MSCM 5322
Volume I

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC
CONTAMINATION CONTROL PROGRAM
REQUIREMENTS
MANUAL
VOLUME I

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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

SEPTEMBER 1970

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FOREWORD

Presented in this document are the requirements for the MSC contamination control program. These requirements are essential to assure the required cleanliness of space systems and elements thereof. MSC organizations shall implement these requirements where applicable.

Appropriate chapters of this document may be contractually invoked in the procurement of hardware by MSC and made a part of the statement of work.

Comments and questions concerning the requirements set forth in this publication or the application of this program should be referred to the MSC Office of Reliability and Quality Assurance.

Manager
Reliability and Quality Assurance

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CHAPTER 1
INTRODUCTION

1.0 INTRODUCTION

1.1 PURPOSE. The MSC Contamination Control Requirements Manual establishes the requirements and criteria for coordinated contamination control activities. This manual was prepared to provide, in a single document, the minimum controls necessary to establish and maintain an effective contamination control program. The facility, operations, and personnel controls, along with the design, development, manufacture, inspection, and test controls, are delineated. Reference to other documents or other chapters within this manual has been held to a minimum to aid the user.

1.2 APPLICABILITY. This manual is applicable to MSC organizations and on-site contractors who are responsible for design, development, manufacture, inspection, and test of space flight or space-flight-related equipment.

1.3 APPLICABLE DOCUMENTS. Applicable documents are delineated in Appendix A and are applicable to the extent indicated herein.

1.4 GOVERNMENT-FURNISHED EQUIPMENT CLEANLINESS REQUIREMENTS. A listing of Government-furnished equipment cleanliness requirements is included in Volume II of MSCM 5322. The cleanliness levels described are minimum requirements and shall govern unless more stringent requirements are stipulated for specific item application.

1.5 MANDATORY REQUIREMENTS. The requirements delineated in MSCM 8080 (Manned Spacecraft Criteria and Standards Program) stipulate additional contamination control requirements that are mandatory. These are listed by Chapter 3, MSC Design and Procedural Standards. The latest issue of MSCM 8080 should be reviewed to ensure that standards relating to contamination control which are issued after publication of this document are also implemented.

1.6 TRADE NAMES. The use of trade names of commercially available products does not constitute an endorsement of those products by the National Aeronautics and Space Administration and it does not imply that there are no other suitable products available.

CHAPTER 2
DEFINITIONS

2.0 DEFINITIONS

2.1 APPLICABILITY. To promote mutual understanding, the following definitions are applicable to this manual.

2.1.1 AGGLOMERATE. A group of particles that have combined to form a larger particle.

2.1.2 AIR SHOWER. A deduster of personnel prior to their entry into the clean room.

2.1.3 AIRBORNE PARTICULATE MATTER. Particulate matter suspended in ambient atmosphere.

2.1.4 AIRLOCK. A small chamber with interlocked doors functioning to maintain pressure during ingress to or egress from the clean room; also, a smaller chamber used for passage of components, tools, etc.

2.1.5 BLANKET. Low pressure gas introduced into a container (or system) to provide an inert atmosphere.

2.1.6 CHECKOUT FLUID. A fluid other than operational fluid for use in evaluating performance of a system; sometimes called test fluid.

2.1.7 CLEAN. That contaminant level just below that which affects the operation or reliability of the part, component, system, or environment.

2.1.8 CLEAN ROOM. A special type of controlled environment facility in which, as a minimum, all incoming air passes through a filter capable of removing a minimum of 99.97 percent of all particles 0.3 micron and larger. In a clean room, temperature, humidity, and pressure are controlled. External sources of particulate contaminants are excluded and internal sources are controlled to the required cleanliness levels.

2.1.9 CLEAN WORK STATION. An individual work bench or similar enclosure which has a HEPA (high-efficiency particulate air) filter and provides essentially laminar flow across the work area.

2.1.10 CLEANLINESS LEVEL. An established maximum of allowable contaminants based on size distribution or quantity in a given area or volume.

2.1.11 CONTAMINANT. Any unwanted foreign material which could be detrimental to the required operation, reliability, or performance of a part, component, subsystem, or system.

2.1.12 CONTAMINANT-SENSITIVE PART. A part whose function may deteriorate with the presence of material(s) other than those for which it was designed. The foreign material may be liquid, gaseous, or solid in nature, with size, number, or character harmful to the operation of the device.

2.1.13 CONTROLLED ENVIRONMENT FACILITY. A specified working area that has the primary objective of controlling one or more physical, chemical, or biological variables.

2.1.14 CONTROLLED WORK AREA. An area where a high degree of cleanliness is maintained by the enforcement of strict controls on personnel access, operations, and facility maintenance as opposed to a clean room where the total environment is controlled by high efficiency air filters, humidity and temperature controls, and the enforcement of more strict personnel and clothing controls.

2.1.15 CONVENTIONAL CLEAN ROOM. A clean room in which the airflow patterns are random.

2.1.16 CRITICAL SURFACE. That surface of a component which directly contacts the system fluids.

2.1.17 CROSSFLOW CLEAN ROOM. A clean room in which the filtered air enters through an entire wall of filters and exhausts through the opposite wall. Air travel within the room is predominantly horizontal.

2.1.18 DECONTAMINATION. This term is commonly applied to the neutralization of hypergolic residues from components (or systems) prior to further handling or storage. This term also may apply to the removal of biological contaminants.

2.1.19 DOP (DIOCTYL PHTHALATE) TEST. DOP aerosol or "smoke" is introduced upstream of the filter at a concentration of 80 to 100 micrograms per liter and the downstream side of the filter is scanned with an aerosol photometer sensitive to 0.3 micron particles.

2.1.20 DOWNFLOW CLEAN ROOM. A clean room in which the air enters through an entire ceiling of filters and is exhausted through the floor. Air travel within the room is predominately vertical.

2.1.21 FIBER. A particle whose length-to-width ratio is in excess of 10 to 1 (minimum length of 100 microns).

2.1.22 FILTER RATING. The capability of a media to restrict passage of matter as established by testing techniques, such as pore size, bubble point, and DOP. Filter ratings for fluid filters include both nominal and absolute ratings. The absolute rating represents the particulate size that the filter will retain with 100 percent efficiency. The nominal rating represents the particulate size retained at a minimum efficiency of 80 percent.

2.1.23 FLUID CONTAMINANT. Liquid, gaseous, or particulate matter suspended or dissolved in a fluid.

2.1.24 FLUSH. A rinsing of a component, system, etc., using a liquid as the rinsing medium.

2.1.25 GROSS CLEANING. Preliminary or rough cleaning to remove scale, rust, metal chips, shop dirt, etc. This cleaning is usually accomplished in a normal working environment to visual inspection standards.

2.1.26 HEPA (HIGH-EFFICIENCY PARTICULATE AIR) FILTER. A filter that is at least 99.97 percent efficient by volume on 0.3 micron particles (DOP test).

2.1.27 LAMINAR FLOW. An unidirectional airflow made up of thin layers. Such flows are common to laminar flow clean rooms and laminar flow benches. For design purposes, laminar flow is an unidirectional flow of a gas or liquid with a Reynolds number (N_R) generally below 2100. $NR = \frac{VdP}{U}$ where V equals velocity in ft./hr., d equals

2 x hydraulic radius in ft., P equals density in lbs./ft.^{3}, and U equals viscosity in lbs./ft. hr.

2.1.28 LIGHT SCATTERING. A technique for detecting, counting, and sizing fluid-borne particulate matter passing through a high-intensity light beam, the distorted light beams being converted to electrical impulses by a photo-multiplier tube and registered on appropriate counters and tapes.

2.1.29 LIMITED LINTING. The term applied to garments and other fabric materials which have been tested and proven to exhibit limited shedding or linting characteristics.

2.1.30 LOCALIZED CLEAN OPERATIONS. Operations conducted under locally maintained environment provided by tenting and conditioned air source.

2.1.31 MEMBRANE FILTER. Porous membrane composed of pure and biologically inert cellulous esters, polyethylene, or other materials.

2.1.32 MICRON. A unit of measurement equal to one-millionth of a meter, twenty-five microns being approximately equal to one-thousandth of an inch (actual 3.937×10^{-5} inch).

2.1.33 MRB. Material Review Board.

2.1.34 NONCRITICAL SURFACE. A surface of a fluid system which does not directly contact the system fluid.

2.1.35 NVR (NONVOLATILE RESIDUE). Soluble (or suspended) material and insoluble particulate matter remaining after controlled evaporation of a filtered volatile liquid, usually measured in grams. Filtration is normally through a 0.45 micron or 0.8 micron membrane filter.

2.1.36 OPERATIONAL FLUID. Fluid used within a fluid system or fluid subsystem as the operational media; fluid downstream of the GSE interface.

2.1.37 ORIFICE. A fixed restriction in a fluid passage to control or measure fluid flow.

2.1.38 PARTICLE. A piece of matter with observable length, width, and thickness usually measured in microns.

2.1.39 PARTICLE COUNTERS. Automatic electronic devices designed to electronically separate, size, and count individual particles.

2.1.40 PARTICULATE MATTER. The general term applied to matter of miniature size, with observable length, width, and thickness, as contrasted to nonparticulate matter without definite dimension.

2.1.41 PRECISION CLEANING. Final or fine cleaning accomplished in a controlled environment to remove minute quantities of contaminants to an established cleanliness level as verified by a rinse sample.

2.1.42 PRECISION CLEANLINESS. The degree of freedom from contaminants that cannot normally be detected by visual means. Detection and measurement of precision cleanliness requires special equipment and techniques.

2.1.43 PRECISION CLEAN PACKAGING. Packaging or protection to preserve precision cleanliness for a specific period and condition.

2.1.44 PRECLEANING. Same as gross cleaning.

2.1.45 PURGE. To flow an inert gas through a system (or line, tank, etc.) for the purpose of ridding the system of a residual fluid or for providing a positive flow of gas from some opening in the system.

2.1.46 RANDOM-FLOW CLEAN ROOM. Air enters the room through diffusers located on or near the ceiling and is exhausted through openings near the floor. The air within this type room follows a random pattern. This type of room is generally identified as a standard clean room.

2.1.47 REFEREE PROPELLANT. A liquid, other than a propellant, which is flowed through a propulsion system for the purpose of system verification, or any other operation, wherein simulated propellant flow is required.

2.1.48 RINSE TEST. A test to determine cleanliness by entrainment or by solution of soluble materials with a suitable rinsing liquid. The liquid is sloshed or agitated

over the critical surfaces of the component to ensure entrainment of particles.

2.1.49 SILT. Particulate matter settled from fluid in the particle size range that is normally not counted. Unacceptable silting is silt in an amount that causes a haze or obscuring of the filter grid lines.

2.1.50 SILTING. An accumulation of minute particles in the size range normally not counted but of sufficient quantity to cause a haze or partial or complete obscuring of either grid lines or any portion of the grid on a test filter membrane when viewed visually or under 40-power (maximum) magnification.

2.1.51 SUBSTITUTE PROPELLANT. Same as referee propellant.

2.1.52 TEST FLUID. A measured volume of fluid which is evaluated by analytical methods to determine its contaminant content; also applicable to fluids used for other test purposes.

2.1.53 TOTAL SOLIDS. The residue from a known volume of liquid which has been evaporated to dryness in an oven.

2.1.54 TUNNEL-FLOW CLEAN ROOM. A room where the incoming air enters through an entire wall of filters and is exhausted through an opposite open area. Air travel within the enclosure is basically laminar.

2.1.55 VISIBLY CLEAN. Visibly clean is defined as the absence of all foreign and harmful particulate and nonparticulate matter visible to the normal unaided eye (corrected vision accepted). Particulate is identified as matter of miniature size with observable length, width, and thickness as contrasted to nonparticulate (film) matter without definite dimension.

2.1.56 VISUAL CLEANLINESS. The degree of freedom from contaminants that may be detected by the unaided eye. Special lighting effects, ultraviolet light, wipe test, water-break tests, and similar means may be used as techniques to determine visual cleanliness. Analytical methods may be employed to determine the degree of visually detected contaminants.

2.1.57 WATERMELON. A low pressure (200 psi) gas sample cylinder of 1.4 cubic feet (39.6 liters) volume.

CHAPTER 3
PROCEDURAL REQUIREMENTS

3.0 PROCEDURAL REQUIREMENTS.

3.1 APPLICABILITY. This chapter lists specific design and procedural standards that are associated with an effective contamination control program. Compliance with these requirements, as applicable, through all phases of assembly, test, checkout, installation, repair, and modification, is required. These requirements are Center policy and cannot be deleted without a waiver from the applicable Program Manager or Functional Director.

STANDARD NUMBER	TITLE
7	Systems Checkout Provisions
14	Threaded Tubing Connectors (B-Nuts) and Sleeves-Stress Corrosion
30	Service Points-Positive Protection from Interchangeability of Fluid Service Lines
38	Fluid System-Design for Flushing
41	Shatterable Materials-Exclusion from Crew Compartment
47	Capping of Servicing and Test Ports Which Are not Required to Function in Flight
51	Beryllium-Restricted Use Within Crew Compartment(s)
62	Threaded Fittings-Restriction on Release of Particles and Foreign Material
63	Metals and Metal Couples-Restriction on Use
64	Nozzles and Vents-Protection Prior to Launch
67	Fluid Supplies-Verification Tests
70	Solutions Which Contain Ethylene Glycol-Requirement for Silver Chelating Agent
78	Cleanliness of Flowing Fluids and Associated Systems
81	Ultrasonic Cleaning of Electrical and Electronic Assemblies
91	Liquid or Gas Containers-Verification of Contents
93	Protection for Tubing, Fittings, and Fluid System Components-Flight Hardware and Associated Equipment
94	Fluid System Cleanliness-Verification in Draining, Purging, and Flushing Operations
97	Fluid Systems-Flushing Requirements
111	Leak Detectors-Wetting Agents
116	Mercury-Restriction on Use
117	Fluid Systems-Review of Cleaning, Flushing, and Purging Procedures
118	Purge Gases-Temperature and Humidity Requirements
120	Breathing Systems-Requirement to Test for Mercury Contamination

CHAPTER 4
PROCUREMENT

4.0 PROCUREMENT OF EQUIPMENT OR SERVICES REQUIRING CONTAMINATION CONTROL.

The procurement of equipment such as spacecraft, major systems, flight-critical ground support equipment, including facilities which directly interface with flight equipment and the procurement of facility repair, modification, or refurbishment services, requires the incorporation of specific contamination control requirements in the purchase request. This chapter delineates these requirements and the method of incorporation. Parts and equipment whose service requirements entail specified precision cleanliness levels shall be cleaned to the required or higher level as detail parts and assembled and packaged in a suitably clean environment (reference Chapters 6 and 7 and Table III). In order to avoid disassembly of equipment to perform required cleaning of detail parts, procurement documents shall specify the cleaning levels and packaging requirements for purchased equipment including reference to this document.

4.1 PROCUREMENT DOCUMENT INITIATION. The initiator of the purchase request should stipulate the cleanliness level required and the test method to be utilized. The cleanliness level and test methods should be chosen from the appropriate tables and chapters of this manual unless more stringent requirements are necessary.

4.1.1 PROCUREMENT REQUIREMENTS. The purchase request should refer to appropriate chapters of this manual to assure incorporation of the MSC approved requirements and procedures.

4.1.2 QUALITY ENGINEERING SUPPORT. The purchase request initiator should request MSC Quality Engineering support when procuring contaminant-sensitive equipment or contamination control services to assure that the appropriate requirements are stipulated.

4.1.3 QUALITY ENGINEERING REVIEW. MSC Quality Engineering shall review purchase requests for the inclusion of contamination control requirements.

4.2 MINIMUM REQUIREMENTS. The requirements stipulated herein are considered the minimum requirements to be incorporated in the purchase request. More stringent requirements may be required for specific systems or services.

4.2.1 MAJOR-MINOR PROCUREMENT. Equipment such as spacecraft, complete systems, contract end items, life sustaining equipment, and flight-critical ground support equipment are considered major procurement items. Small items or hardware that will be incorporated into other systems or equipment are considered minor procurement items.

4.2.2 MAJOR PROCUREMENT. When major items or services are procured, the following contamination control requirements should be included in the purchase request as applicable.

4.2.2.1 A contamination control program plan shall be developed to specify the methods, procedures, and processes to be utilized to control contamination. This plan shall also specify the type of facility to be utilized, the specific cleanliness levels to be achieved, and the method of certifying the cleanliness of the end product. MSC approval of this plan is required.

4.2.2.2 Product cleanliness certification shall accompany each item; such certification shall be traceable to the applicable test method and data by appropriate records.

4.2.2.3 Process and procedural controls shall be initiated to assure that item contamination does not occur as a result of material/fluid incompatibility or as a result of residuals from the cleaning processes.

4.2.3 MINOR PROCUREMENT. Procurement of equipment or services not considered as major items shall require compliance with 4.2.2.2 and 3. A contamination control program plan as described in 4.2.2.1 is not required for minor procurement items.

CHAPTER 5
RECEIVING INSPECTION

5.0 RECEIVING INSPECTION

The receipt inspection of procured precision-cleaned items is required to assure that storage, transit, and handling of the packaged item has not voided the cleanliness integrity. Precision cleanliness may be voided by inadequate supplemental packaging, packing damage during shipment, or may be the result of an improper packaging method being utilized at the time the part was cleaned. Receipt inspection shall, as a minimum, consist of the inspections listed herein.

5.1 PACKAGING. Item packaging shall be inspected to verify that, as a minimum, the requirements of 12.1.4 and 12.2 through 12.7 have been met.

5.2 PACKAGING INSPECTION. A visual inspection of the precision-clean packaging integrity shall be performed. Items contained in packages where the seal integrity has been violated shall be returned to the supplier or routed for cleaning and certification.

5.3 ITEM INSPECTION. Visible evidence of item damage from transit, handling, packaging, or other causes shall be cause for rejection.

5.4 PACKAGING REMOVAL. Precision-clean packaging shall not be removed unless such removal is within the confines of a clean area that will not degrade the item cleanliness. Upon completion of receiving inspection the item shall be repackaged prior to return to stock if the item cleanliness has not been violated. In those cases where item cleanliness cannot be assured, the item must be recleaned prior to repackaging.

5.5 DOCUMENTATION. Precision-cleaned items received from contractors shall be inspected for documentation meeting the purchase order requirements and item certification level of cleanliness. Such documentation and item certification shall be maintained as a permanent record traceable to the item received.

CHAPTER 6
CLEAN ROOM REQUIREMENTS

6.0 CLEAN ROOM REQUIREMENTS

Clean rooms used for the cleaning, assembly, testing, and packaging of precision-cleaned items shall be governed by the requirements of this chapter.

This chapter describes classes of environmental air control within clean rooms. It also prescribes air cleanliness classes and certain other environmental air conditions required for achieving and maintaining specified cleanliness levels.

6.1 CLEAN ROOM CLASSES. In general, items which have clearances in a range from 100 to 1000 millionths of an inch are affected by particle sizes from 2.5 to 25 microns. These items will require environmental control and should be overhauled in at least a class 100,000 clean room. Clearances less than 100 millionths of an inch (2.5 microns) will require the use of a class 100 or 10,000 clean room.

Three air cleanliness classes are established by this document. Table II, on which these classes are based, shows statistical distribution curves for average particle sizes. Classifications are based on particle count with a maximum allowable number of particles per unit volume of air permissible, 0.5 micron and larger or 5.0 microns and larger. Particle counts are to be taken during work activity periods and at a location which will yield the particle count of the air as it approaches the work location. Table III compares clean room classes versus equipment critical surface cleanliness levels. This table should be used as a guide for selecting the class of clean room to be utilized for specific operations.

6.2 CLEAN ROOM DESIGN

6.2.1 CONVENTIONAL CLEAN ROOM (NONLAMINAR FLOW DESIGN). The nonlaminar flow clean room makes use of highly filtered and conditioned air brought into the area through individual diffusers located in or around the ceiling of the room. Emphasis shall be placed on limiting the amount of contaminants introduced into the air in the room by controlling the personnel, operations, and materials inside the facility. Personnel shall be required to wear low particle shedding type garments, and all materials shall

be cleaned before introduction into the area. Removal of contaminants should be through adequate maintenance and janitorial service.

6.2.2 LAMINAR FLOW CLEAN ROOM. The laminar flow clean room utilizes highly filtered and conditioned air brought into the room towards the work area through a filter bank comprising an entire wall or ceiling of the room and exhausted through a similar entire surface normally facing the air inlet filter bank. The air is moved through the room in a laminar flow fashion, thus making only a single pass through any given area of the room. The laminar flow air movement carries out of the room any released contaminants brought into the room on personnel and equipment and airborne contaminants generated by operations in the room. Contaminants generated in localized areas of the room are isolated from other areas by the striations of the laminar airflow. Emphasis shall be placed on performing critical work in the undisturbed flow of clean air from the incoming air surface. Personnel restrictions, equipment cleanup, and operational limitations are minimized in the laminar flow clean room.

6.2.3 TUNNEL FLOW CLEAN ROOM. The tunnel flow clean room is normally a laminar flow clean enclosure within a larger nonlaminar flow room. Conditioned air is brought into the room at one end of the tunnel and travels the length of the tunnel in laminar flow. The air then exits into the ambient atmosphere.

6.2.4 EQUIPMENT MOUNTING. Rotating equipment, such as motors, fans, or blowers (which may be sources of vibration), shall not be mounted on or supported by the walls or ceiling of the clean room shell unless adequately insulated to prevent vibration induced contaminants from being introduced to the clean atmosphere.

6.3 AIRBORNE CONTAMINATION. Airborne particle concentrations shall be measured at representative locations in the clean room. Different measuring techniques shall be employed in nonlaminar and laminar airflow clean rooms. Contaminants generated in nonlaminar flow rooms tend to be diffused over the entire work area generally, and thus airborne particle counts will be fairly uniform through the whole work area.

In laminar flow clean rooms, airborne contaminants released into the work area will follow the airstream path toward the exit.

Therefore, contaminant levels in these devices will vary to a marked degree from class 100 to the specific contaminant level downstream of the dirtiest operation. Thus, in a laminar flow facility, the sample of air shall be taken from the air as it approaches the area of interest. In nonlaminar flow clean rooms, airborne contamination tends to disperse throughout the area. However, particle count shall be taken at work height level and in the general work activity areas.

6.3.1 AIRBORNE PARTICLE MONITORING. Particulate contamination of the clean room should be determined at various periods during the work cycle to ascertain peak contamination times. The clean room shall then be monitored at least once daily during these periods of greatest contaminant generation (normally during those periods of greatest occupancy).

Manual microscopic methods are adequate for monitoring air in the class 10,000 to 100,000 range. When measuring air in facilities below the 10,000 range, so few 5.0 microns and larger particles will be present that the manual method may not pick up enough of these size particles to produce a statistically valid determination. Therefore, air monitoring in the range below class 10,000 should only be done with light-scattering equipment or other approved instrumented techniques.

For particle size 0.5 micron and larger, equipment employing light-scattering principles shall be used as specified in ASTM F50-65T. For particle sizes 5.0 microns and larger, microscopic counting of particles collected on a membrane filter, through which a sample of air has been drawn, may be used as specified in ASTM F25-63T and SAE-ARP-743.

Monitoring a laminar flow clean room shall be accomplished by using standard environmental instruments. Since these facilities have an airflow with a general direction and velocities, values monitored are indicative of conditions existing upstream.

6.4 TEMPERATURE RANGE. Temperature in the clean room areas shall be maintained around a nominal temperature of 72°F. with the exception of those laboratories or work areas for which other temperatures may be necessary for control of stability of items being fabricated or tested, in which case the nominal temperature shall be specified. The temperature variation at the control point may range from ±1.0°F. in the most critical operations to as much as ±5.0°F.

6.4.1 TEMPERATURE MONITORING. Temperature monitoring may be achieved by the use of conventional temperature monitoring devices, the simplest of these being a conventional Fahrenheit thermometer. More automated devices may be used as a supplement to the thermometer, but these devices should be checked at least daily against the thermometer. Alarm devices may be installed with the automated devices. Normally, hourly checks of temperature will be sufficient since supervisors can be expected to notice unusual variations which may occur between checks.

If the product being processed is extremely sensitive to temperature rate of change, it may be necessary to monitor this value with an automated temperature recording device. In such cases, the temperature probe should be in the proximity of the product where temperature rate of change is critical. Warning or alarm devices can be employed if it is determined that the product is sensitive to temperature rate of change.

6.5 RELATIVE HUMIDITY RANGE. Choice of relative humidity range shall be based primarily upon the product requirements. Rusting of parts can occur and become a serious problem at relative humidities above 50 percent. Electrical static charges on dielectric materials or parts can cause problems due to particle attraction at low relative humidities. A value of 30 percent relative humidity should be established as a minimum.

6.5.1 HUMIDITY MONITORING. Humidity monitoring may be achieved by use of a conventional wet and dry bulb thermometer used in conjunction with a psychrometric chart. More automated devices may be used as a supplement to the wet and dry bulb thermometer. If more automated devices are used, they should be checked against a wet and dry thermometer at least once weekly. Mercury thermometers are not permitted unless approved for specific application by MSC Quality Engineering.

6.6 MAKEUP AIR. In rooms utilizing a relatively low volume of recirculated air, makeup shall be specified as a percentage of the incoming air into the room, e.g., 20 percent fresh air makeup. In rooms utilizing a high volume of recirculated air, makeup air shall be specified as a given volume per minute, e.g., 30 cubic feet per minute per person. When vented hoods are used for vapor control, makeup air volume shall be greater than that of the exhausted air in order to maintain a positive pressure in the room. Noxious vapor control shall be complete and positive.

6.7 POSITIVE PRESSURE. The minimum positive pressure differential between the room and any adjacent area of less clean requirements shall be 0.05 inch of water, with all entryways closed. When the entryways are open, the blower capacity shall be adequate to maintain an outward flow of air. This is to minimize contaminants migrating into the room.

6.7.1 PRESSURE MONITORING. Pressure monitoring may be achieved by use of a simple nonmercury type "U" tube manometer with each opening vented in such a manner that the pressure differential is measured between clean room and its outside surroundings. A nonmercury type pressure differential gage capable of measuring several inches of water pressure and clearly indicating a 0.01 inch of water reading may be substituted for the manometer.

6.8 DESIGN INFORMATION

6.8.1 NONLAMINAR FLOW CLEAN ROOM

6.8.1.1 CLEAN ROOM SHELL. The clean room shell, floor, walls, and ceiling shall be designed and constructed with materials and in such a manner as to eliminate air leaks into or from the room. The walls and ceiling material shall be low shedding and easy to clean. The floor covering shall be low particle shedding and sufficiently durable to withstand wear imposed by traffic and clean room operations.

6.8.1.2 ENTRYWAYS. Entryways, doors, and pass-throughs shall be of correct size to permit personnel and required equipment access to the clean room. These entryways shall be the airlock type and should provide air seals sufficient to allow pressurization of the clean room. Double interlocking doors shall be provided to prevent loss of pressure in the clean room.

6.8.1.3 ANTEROOMS. Anterooms shall be provided for clean room personnel clothing change area, clothing storage, washup facilities, air showers, and other equipment for personnel clean room entry requirements. Anterooms may also be provided, as needed, to house parts cleaning and other room support equipment.

6.8.1.4 AIR SUPPLY AND FILTRATION EQUIPMENT. Air supply and filtration equipment shall be provided to filter all air entering the clean room, recirculated as well as fresh air. A 3-minute room air change is usually considered to be minimum for 8 to 12 feet ceiling height rooms. Equipment shall be provided to supply fresh or makeup air, as required.

6.8.1.5 CLEAN ROOM FURNITURE. Clean room furniture shall be constructed of materials which exhibit a minimum of chipping, flaking, oxidizing, or other deterioration. Paint should be hard and nonflaking, such as an epoxy. For furniture subjected to abrasion and bumping, stainless steel or laminated plastic surfaces should be chosen.

6.8.1.6 CLEAN ROOM LIGHTING EQUIPMENT. Clean room lighting equipment shall be provided to meet work requirements within the clean room. Shadowless, uniform lighting at intensity levels of 100 to 150 foot-candles at work position is satisfactory for most clean rooms. Ceiling light fixtures shall be flush mounted and sealed to prevent air leaks. Lights should be accessible from above and outside the clean room, not from within the clean room.

6.8.2 LAMINAR FLOW ROOM

6.8.2.1 CLEAN ROOM SHELL. Laminar airflow rooms shall have floor, walls, and ceiling assembled in such a manner so as to inhibit the leaking of any air into or from the room. The materials for walls and ceiling shall be low shedding and the finish shall be readily cleanable. Floor covering shall have low shedding characteristics and shall be able to withstand wear imposed by personnel and operations within the room.

6.8.2.2 ENTRYWAYS. Entryways, doors, and pass-throughs shall be of sufficient size to permit entrance and exit of personnel and required equipment. These openings shall provide an air seal when closed to allow pressurization of the area.

6.8.2.3 ANTEROOMS. Anterooms shall be provided for storage of personnel clothing and personal belongings, washing facilities, and cleaning equipment.

6.8.2.4 CLEAN ROOM FURNISHINGS. Clean room furniture shall be constructed of materials which exhibit a minimum of chipping, flaking, oxidizing, or other deterioration. Paint should be hard and nonflaking, such as epoxy. For furniture subjected to abrasion and bumping, stainless steel or laminated plastic surfaces should be chosen. Air-conditioning equipment for cooling, heating, humidification, and dehumidification of the clean room air supply shall be provided as required.

6.8.2.5 CLEAN ROOM LIGHTING EQUIPMENT. Shadowless, uniform lighting at intensity levels satisfactory at normal working levels shall be designated as required. Ceiling lighting fixtures may be suspended into the clean room to eliminate the necessity for sealing, but such fixtures shall be as streamlined as possible. If the ceiling height is exceptionally low, it would be proper to employ recessed and sealed fixtures. An intensity level range of 100 to 150 foot-candles at work position shall be required.

6.8.2.6 LAMINAR AIRFLOW CONFIGURATIONS

6.8.2.6.1 WALL-TO-FLOOR AIRFLOW. This design is adaptable to a wide choice of sizes, inasmuch as the length is limited only by the space available.

6.8.2.6.2 CEILING-TO-FLOOR AIRFLOW. This vertical airflow design has the capability of providing the highest degree of clean atmosphere because any contaminants generated by a particular operation are immediately carried down and out of the room. This provides an opportunity to perform many operations, such as functional testing, which otherwise would be required to be accomplished elsewhere.

6.8.2.6.3 WALL-TO-WALL AIRFLOW. Horizontal rooms represent a low investment with a potential for a high degree of contamination control.

6.8.2.6.4 ROOM-WITHIN-A-ROOM TUNNEL AIRFLOW FACILITIES. Employing a filter bank (normally a combination of prefabricated modules) and inexpensive side walls and ceiling with an open exhaust end opposite to the filter bank, this facility resembles a tunnel of any height, width, and length the user requires. This type of installation is the least costly of any type of room, and can be disassembled and moved with a minimum of time and effort. Its effectiveness is comparable to the normal horizontal laminar flow room. This type of facility normally may not be used where temperature or humidity controls are required.

Acceptable temporary clean room areas have been constructed using prefabricated modules (which are complete units containing both supply fan and HEPA filters) and flexible plastic walls and ceilings with a completely open end. The clean room area in this case resembles a plastic tube, and the ceilings and side walls are supported by a simple exterior pipe or angle iron framework.

6.8.2.6.5 MOBILE CURTAINED DOWNFLOW UNIT. This piece of equipment may be constructed in a wide choice of sizes and heights, and is useful for providing a high degree of contamination control for large and difficult-to-move structures on which assembly must be accomplished under exacting controlled conditions.

6.8.2.7 INCOMING AIR FILTER BANK. The incoming air filter bank of a laminar flow room shall cover either one entire wall or the entire ceiling. When built-in benches are included at the incoming air end of the room, the wall filter bank may be

modified to cover only the area extending from the bench working surface to the ceiling. In every instance, a laminar airflow room shall be class 100 in the zone immediately adjacent to the incoming air entry area.

6.8.2.8 FINAL FILTERS. All final filters shall be of the HEPA type, or better. For laminar flow installations HEPA filters in which pinhole and other localized leaks have been sealed off shall be specified. DOP smoke penetration test ratings shall include testing for penetration through filter gaskets, if present.

6.8.2.9 PREFILTERS. Prefilters shall be used on all fresh air makeup supply and on recirculated air to prolong the life of HEPA filters. Efficiency of the prefilters shall be tailored to the anticipated contaminant load.

6.8.2.10 AIR EXIT. The air exit from these rooms shall consist of an entire wall or grated floor surface. The use of prefiltration located back of the exit wall grilles, or beneath the grated or perforated floor, will provide pressure drop across the exit area to help assure a uniform room airflow.

6.8.2.11 AIRFLOW VELOCITY. Airflow velocity through the cross section of the room normally shall be maintained at 90 feet per minute with a uniformity of $\pm$20 feet per minute throughout the undisturbed room area. When the delta pressure across the filter is such that airflow velocity cannot be attained or maintained, the filter should be changed.

6.8.2.12 AIRFLOW PATTERNS. Airflow patterns shall be uniform and with a minimum of turbulent airflow patterns throughout the undisturbed portions of the clean room.

6.9 OPERATIONAL REQUIREMENTS. Good housekeeping practices are of prime importance in clean rooms. When cleaning a room, it should be kept in mind that the mere addition of cleaning personnel to the environment will increase the contamination level in the room. Therefore, the times the rooms are cleaned shall be chosen with care. The room should preferably be

cleaned when no work is being performed in the room. Cleanup time of the air will be rapid because of high air velocity and laminar flow characteristics in the laminar flow room.

Air cleanup time will be considerably longer in the nonlaminar flow room. Minor floor and bench vacuuming can be performed during room operation. When a major cleaning must take place during operation of the room, work downstream of the activity and in the near vicinity of the housekeeping operation shall cease until proper environmental conditions are established.

All equipment shall be cleaned before entry into a clean room area by dusting, vacuuming, washing, or by suitable means, as best suited to equipment involved.

The use of tobacco, eating, drinking, and cosmetics in any form shall not be permitted in the clean room area.

Gloves, finger cots, tweezers, or other handling methods and equipment shall be used while working with or handling sensitive parts to avoid contamination of those parts by loose skin, natural skin oils, or perspiration.

No abrasive instruments such as files, steel wool, abrasive papers, etc., shall be allowed in clean room areas.

Tools and equipment used in clean room areas shall be limited to those actually required for operations. Clean room entryways shall utilize a sticky mat or magna rug at the entrance to the clean room to remove dust and dirt from the soles of the shoes or foot coverings. Mats or rugs shall be replaced as necessary to assure the tacky or chemical cleaning capabilities are maintained.

6.9.1 NONLAMINAR FLOW CLEAN ROOM. Access to the clean room area shall be limited to only those persons necessary for the area operation.

Shoes shall be changed, covered, or cleaned before entering the clean room area.

Use of compressed air or other high velocity gases for blowoff or cleaning operations, except under exhaust hoods capable of carrying residue to exterior of the clean room, shall be avoided.

Room maintenance operations shall be restricted during normal clean room operations to avoid airborne particle generation. When contaminant producing emergency or

routine maintenance is required, normal work shall be halted until room is cleaned.

Janitorial service to the room shall consist of a properly supervised, regularly scheduled cleaning program.

Airborne particle controlled hoods or work stations shall be used where feasible. These hoods should provide a high degree of cleanliness at reasonable costs.

6.9.2 CEILING-TO-FLOOR AND WALL-TO-FLOOR LAMINAR FLOW CLEAN ROOM. Checks shall be made for proper operation of a room (correct airflow, velocity, uniformity, and properly sealed filters).

The clean room blowers shall run continuously, if possible, or at a minimum, be started 15 minutes before use of the room.

6.9.3 CROSSFLOW AND TUNNEL HORIZONTAL LAMINAR FLOW CLEAN ROOM. Checks shall be made for proper operation of the room, correct airflow, velocity, and uniformity. The proper sealing of the filters shall be verified.

The clean room blowers shall run continuously, if possible, or at a minimum, be started 15 minutes before use of the room.

Operations shall be graded according to cleanliness levels required for critical work. The most critical operation shall be nearest the filter bank.

Obstructions to the airflow shall be kept to a minimum, particularly upstream from critical work.

Arrangement of the furniture in the room shall be made to allow as free an airflow across the room as is possible.

CHAPTER 7
LAMINAR FLOW CLEAN WORK STATIONS

7 0 LAMINAR FLOW CLEAN WORK STATION REQUIREMENTS

The procedures for operating, monitoring, maintaining, sampling, and inspecting laminar flow clean work stations shall be in accordance with the requirements of this chapter.

7.1 GENERAL REQUIREMENTS. Laminar flow clean work stations, in theory, are designed to provide a class 100 environment over a given localized work operation whether the station is operating in a controlled or noncontrolled ambient. In practice, the station may be classified to a lesser controlled class (for example, class 10,000) of environment as determined by the specific application for which it is utilized.

7.1.1 DOP TEST. DOP (dioctyl phthalate) aerosol or "smoke" is introduced upstream of the filter at a concentration of 80 to 100 micrograms per liter and the downstream side of the filter is scanned with an aerosol photometer sensitive to 0.3 micron particles.

7.1.2 CLASSIFICATION. The using organization will determine what class of air cleanliness the clean work station will be certified and monitored to, depending upon product or test requirements. However, as a maximum, a clean work station should not be certified or operated to a lesser controlled environment than class 10,000.

7.1.3 LAMINAR FLOW CLEAN WORK STATION OPERATION. Operations within the laminar flow clean work station require the same personnel, handling, and packaging requirements that are observed in the operation of a clean room.

7.1.4 EVALUATION OF THE AMBIENT. Although the clean work station is designed to operate in an uncontrolled ambient, the immediate surroundings should be evaluated. Particles generated around the station may penetrate the laminar air stream or follow the worker's arms into the station. The area should also be checked for any other operations producing high velocity air, particles, or vapors which could be introduced to, interfere with, or penetrate the air stream.

7.1.5 PERSONNEL. Proper personnel operating techniques are required to control contamination which is carried into the bench on hands, tools, fixtures, etc., and deposited on working surfaces. When the bench is operated in an uncontrolled ambient there is a greater susceptibility of material transported in and out of the station to carry contamination with it which will be transferred to the work bench surface. The same is true for the worker's hands.

7.1.5.1 Care should be taken to assure that hands, sleeves, etc., are clean and free of loose dirt and lint before placing them inside the clean work station. Smocks with snug fitting wristbands, caps, and gloves should be as outlined in Chapter 10.

7.1.5.2 Clean gloves used to handle parts must not be used to handle material outside the clean work station and then returned to the station.

7.1.5.3 If close inspection of the work piece is required where the worker must lean over the part, properly worn head covering is essential.

7.1.6 WORK PIECE EQUIPMENT CONTROL

7.1.6.1 MATERIALS. All materials (work pieces, tools, containers, jigs, etc.) should be free of visible particulate matter before being placed inside the station.

7.1.6.2 EQUIPMENT. In bench type work stations, the bench section should be kept as free as possible of any material not immediately used. Any material that must be kept inside the station should be stored along the sides of the work station. Nothing is to be placed along the back edge of the work station between the work piece and the filters.

7.1.6.3 PAPER PRODUCTS. Papers and paper products are not allowed inside a clean work station.

7.1.6.4 WRITING DEVICES. Lead pencils are not allowed inside the clean work station; only nonretractable ballpoint pens may be used.

7.2 HEPA FILTERS. All HEPA filters shall be checked prior to installation in a clean work station by the DOP test to certify that no pinhole leaks exist in the filter media and that the media is properly sealed to the filter frame. A filter manufacturer's certification may be accepted in lieu of the performance of the test by the using organization.

7.3 TESTING OF INSTALLED HEPA FILTERS. Two tests are necessary to ensure that the clean work station is operating reliably and, therefore, providing a specified class of air cleanliness. These tests shall be made on all new clean work station installations, when any of the HEPA filters are changed, or when the unit is moved.

7.3.1 AIRFLOW TEST. The airflow test may be performed by either the velometer or anemometer method according to sections 7.6.1 and 7.6.2.

7.3.2 LEAK TEST. The leak test may be performed by either the DOP test or the particle counter scanning test according to sections 7.7.1 and 7.7.2.

7 4 MONITORING CLEAN WORK STATIONS. Clean work stations in use shall be monitored at least once each 8-hour shift until a pattern of reliability is established; thereafter, they shall be monitored on 30-day cycles as follows:

7.4.1 APPARATUS. An automatic particle counter having a sampling rate of at least 0.1 cubic foot per minute is required. The instrument shall be equipped with a flexible sampling tube and the sampling tube inlet shall be approximately 7/16 inch I.D. to provide for isokinetic sampling or, as an alternate, an approved vacuum sampling device may be used.

7.4.2 SAMPLING. At least two critical workpoints within the clean work station shall be sampled. Where a station has more than two workpoints, all such workpoints shall be sampled. The sampling tube inlet of the particle counter shall be rigidly positioned, i.e., not handheld, in the direction of airflow at the workpoint.

7.4.3 PROCEDURE

7.4.3.1 CALIBRATION. When an automatic particle counter is used, ascertain that the particle counter has been calibrated in accordance with the

manufacturer's instructions and/or established calibration requirements.

7.4.3.2 OPERATING TIME. Ascertain that the clean work station has been turned on and has been operating for at least 15 minutes prior to sampling.

7.4.3.3 SAMPLING. Obtain a minimum of five 1-minute counts at each workpoint and convert data to particles per cubic foot as applicable.

7.4.3.4 SAMPLE RECORDING. Record the high, low, and average counts for each workpoint.

7.4.3.5 SAMPLE AVERAGING. Whenever the average count for a workpoint exceeds the air classification requirement of the clean work station corrective action is indicated.

7.5 MAINTENANCE. Clean work stations shall be maintained as described herein.

7.5.1 UNCONTROLLED AMBIENT. For clean work stations operated in an uncontrolled ambient, the prefilters shall be replaced or cleaned at least once a month. Cleaning may be accomplished by vacuuming or in accordance with the manufacturer's instructions.

7.5.2 CONTROLLED AMBIENT. For clean work stations operated in a controlled ambient, class 100,000 or better, the prefilters shall be cleaned or replaced at least once every 3 months, when in continuous use or on an approximate equivalent use time basis when the work station is not in continuous use.

7.5.3 INSPECTIONS. At least semiannually, clean work stations shall be given a general electrical and mechanical inspection.

7.5.4 PERFORMANCE EVALUATION. At least semiannually, the clean work stations shall be given a "performance reevaluation." This "performance reevaluation" includes an airflow test according to section 7.6.1 or 7.6.2 and a leak test according to section 7.7.1 or 7.7.2.

7.5.5 CLEANING THE CLEAN WORK STATION. Work station cleaning shall be accomplished in accordance with the schedule and methods defined herein.

7.5.5.1 SCREEN CLEANING. If a protective screen is provided in front of the filters, it should be cleaned to remove any particles before work begins. A vacuum device with a plastic intake nozzle is recommended for this cleaning. All sensitive material must be removed from the station or properly covered during this operation.

7.5.5.2 WORK SURFACES. After the screen has been cleaned and the air supply is operating, the work surface should be wiped thoroughly with a clean polyurethane wiper dampened with filtered isopropyl alcohol.

7.5.5.3 CLEANING SCHEDULE. The work surface should be wiped as stated above at least once each shift. More frequent wiping may be required if much material is carried in and out of the station.

7.6 AIRFLOW TESTS. The airflow test is made to determine that a proper laminar airflow is being maintained across the opening of the clean work station. Either of the following test methods may be used.

7.6.1 VELOMETER METHOD.

7.6.1.1 A calibrated airflow velocity meter is required which is capable of measuring the expected airflow, 90±20 feet per minute.

7.6.1.2 With the air supply to the clean work station operating, measure the airflow velocity parallel to the face of the final filter(s) at a distance from the filter(s) of 6 to 12 inches.

7.6.1.3 The airflow should be measured continuously by starting at one corner and moving the velometer slowly across the filter(s) and then back across at a higher or lower level until the entire filter(s) has been scanned.

7.6.1.4 The velocity shall be noted as the velometer moves across the filter(s).

7.6.1.5 One velocity reading shall be taken at the center of the inlet duct and 5 to 8 inches in front of the grill.

7.6.2 ANEMOMETER METHOD

7.6.2.1 A calibrated hot-wire anemometer (thermocouple probe) instrument with an accuracy of ±5 percent of the indicated value is required. Calibration shall be checked before and immediately following the test; the hot wire shall be checked to ensure that there is no oxide buildup.

7.6.2.2 With the air supply to the clean work station operating, all readings shall be taken in a plane parallel to and 6 to 12 inches downstream of the final filter(s). Readings shall be taken at 6- to 10-inch intervals along both an x and y axis in the parallel plane.

7.6.2.3 One velocity reading shall be taken at the center of the inlet duct and 3 to 5 inches out from the grill.

7.6.3 AIRFLOW RECORDING. The arithmetic average reading, the maximum reading, the minimum reading, and inlet reading shall be reported.

7.6.4 REQUIREMENT FOR CORRECTIVE ACTION. The following results indicate corrective action is required.

7.6.4.1 "Dead spots" or extremely low velocity points of less than 70 feet per minute.

7.6.4.2 Excessively high velocity points (which may indicate a leak) greater than 110 feet per minute.

7.6.4.3 An overall variation exceeding 25 feet per minute.

7.6.4.4 An average velocity less than 75 feet per minute.

7.7 LEAK TEST PROCEDURES. The leak test is made to determine that the final filter(s) is properly sealed and, therefore, not leaking contaminated air. Either of the following test methods may be used.

7.7.1 DOP TEST

7.7.1.1 Test smoke shall be DOP generated with a Laskin type nozzle and introduced into the inlet ducts of the clean work station while the blowers are operating.

7.7.1.1.1 Using linear readout photometers, the upstream concentration shall be established using one DOP-generating Laskin nozzle for each 500 cfm of test airflow or increment thereof. The instrument shall be adjusted to read 100 percent. Upstream concentration shall be measured immediately ahead of the HEPA filter(s), or

7.7.1.1.2 Using logarithmic readout photometers, the upstream concentration shall be adjusted, using the instrument calibration curve, to give a concentration of 1.0×10^{4} above that concentration required to give a reading of one division on the dial. Upstream concentration shall be measured immediately ahead of the HEPA filters.

7.7.1.2 Test photometer shall have a sample flow rate of 1 cubic foot of air per minute. Probe shall be flexible sampling tube with an inlet of sufficient area (1 to 1.5 square inches) to maintain probe inlet velocity at or slightly higher than the 100 feet per minute flow rate through the filter. Probe shall be held 1 to 2 inches from the filter's face.

7.7.1.3 The filter(s) and the perimeter of the filter(s) shall be scanned by passing the probe in slightly overlapping strokes so that the entire area of the filter(s) is sampled. Separate passes shall be made around the entire periphery of the filter(s), along the bond between the filter and the frame, and along the seal between the filter frame and the clean work station at a traverse rate of not more than 10 feet per minute.

7.7.1.4 A leak is defined as a photometer reading as follows:

7.7.1.4.1 For linear instruments: Greater than 0.01 percent.

7.7.1.4.2 For logarithmic instruments: Greater than one scale division.

7.7.2 PARTICLE COUNTER SCANNING TEST

7.7.2.1 APPARATUS. A particle counter having a sampling rate of at least 0.1 cfm, and equipped with a flexible sampling tube having an inlet opening sized to provide isokinetic sampling (e.g., with 100 fpm air velocity in the clean air device and 0.1 cfm sampling rate, the sample tube inlet should be approximately 7/16 inch I.D.).

7.7.2.2 Operate clean work station at least 15 minutes before starting test.

7.7.2.3 CALIBRATION - PARTICLE COUNTER

7.7.2.3.1 Calibrate in accordance with manufacturer's instructions and/or established calibration requirements; place in operation with the sampling tube inlet (probe) immediately downstream of the center of a HEPA filter.

7.7.2.3.2 Allow counter to operate until stable readings are obtained. Remove probe from clean airstream and sample the ambient to verify that the ambient particle concentration is at least 100,000 particles each cubic foot larger than 0.5 micron. If the ambient concentration is less than this level, a DOP generator shall be operated to raise the concentration on the inlet or upstream side of the filter(s).

7.7.2.3.3 Return probe to the clean airstream at the center of the HEPA filter and allow unit to operate until stable readings are again obtained.

7.7.2.4 Probe shall be held 1 to 2 inches from the filter(s) face. The filter(s) and the perimeter of the filter(s) shall be scanned by passing the probe in slightly overlapping strokes so that the entire area of the filter(s) is sampled. Separate

passes shall be made around the entire periphery of the filter(s), along the bond between the filter frame and the clean work station at a traverse rate of not more than 6 feet each minute.

7.7.2.5 A leak is defined as a sustained particle concentration in excess of 100 particles per cubic foot larger than 0.5 micron.

7.7.2.6 PRECAUTIONS

7.7.2.6.1 Periodic surges and unsustained particle counter readings are not indicative of leaks, but are merely burst releases of particles from crevices, etc.

7.7.2.6.2 Leaks are normally characterized by indicated concentration levels in excess of 1000 to 2000 particles per cubic foot with the particle counter.

7.7.2.6.3 Concentration levels in the range of 100 to 500 per cubic foot with the particle counter method may be indicative of instrument contamination or particle release from crevices, etc., rather than actual leakage. In such cases, the vicinity of the suspected leak should be recleaned and the particle counter restandardized with the sample inlet immediately downstream of the HEPA filter. A recheck of the suspected point will then verify if a leak actually exists.

7.7.2.7 CORRECTION OF DETECTED LEAKS. If a leak is detected, determine if the leak is in the filter itself or coming around the filter (indicating a poor seal). Small pinhole leaks in the filter may be repaired with RTV silicone. Tightening filter clamps may correct poor seals or seat sealing gaskets properly. If these corrections do not correct the leak, the filter should be replaced.

7.7.3 CERTIFICATION. A certification decal shall be affixed to all clean work stations. This decal shall specify the environment classification and the date of initial certification.

7.7.4 INSPECTION RECORDS. Inspection maintenance and monitoring records shall be maintained for each clean work station.

CHAPTER 8
CONTROLLED WORK AREA

8.0 CONTROLLED WORK AREA

Environmentally and contamination controlled laboratories, special workrooms, vacuum chambers, or other designated facilities which are not clean rooms as defined in Chapter 6, but do meet the minimum requirements of this chapter, may be identified as controlled work areas. The cognizant organization at each site shall designate the controlled work areas as determined by the type of work and/or the test article requirements. When a facility is designated as a controlled work area, it shall be controlled according to the requirements delineated herein.

8.1 SCOPE. These requirements are applicable and may be used where a high degree of shop cleanliness is required. Applicability of these requirements includes, but is not limited to, facilities such as any suitably enclosed room, Environmental Test Chambers, or the immediate vicinity of a spacecraft. Housekeeping procedures, personnel controls, and contaminant-generation constraints are specified to obtain and maintain an acceptable level of work area cleanliness and to protect, as applicable, workpiece cleanliness.

8.2 REQUIREMENTS.

8.2.1 FACILITY REQUIREMENTS

8.2.1.1 The controlled work area or the environment surrounding the controlled work area (such as where a controlled work area has been established in the immediate vicinity of a spacecraft) shall be air-conditioned and the air supply shall be filtered. Filters shall remove most airborne particulates and may be of the cleanable or throwaway type; filters shall be cleaned or changed as required. Newly established controlled work areas shall have the filters cleaned or replaced until documented evidence indicates extended maintenance schedules should be initiated.

8.2.1.2 Temperature may be controlled for personnel comfort; however, humidity shall be controlled to the extent necessary to prevent condensation or corrosion on any and all surfaces, or to preclude buildup of electrical static charges.

8.2.1.3 A space shall be provided at the entrance to the controlled work area for storage of clean room garments and for dressing. This area shall be separated from enclosed rooms, by an enclosed anteroom, or by a partition. This partitioning may consist of nonflammable plastic curtains.

8.2.1.4 Controlled work areas shall be protected from overhead operations such as cranes, hi-lifts, facility maintenance, etc. Nonflammable plastic covering may be used for this purpose.

8.2.1.5 Compressed gas shall be supplied from a source that is equipped with dehydrators and filters capable of removing all types of contamination, and regular maintenance shall be scheduled and recorded on this equipment.

8.3 MAINTENANCE OF THE CONTROLLED WORK AREA

8.3.1 Sweeping and sweeping compounds will not be permitted in controlled work areas.

8.3.2 Floors will be vacuumed at least once each 8-hour shift (this is not required during test preparations which require more than 8 hours for test conduct), or more frequently if required, to maintain a visibly clean condition. Vacuum source shall be either located outside of the controlled work area or shall be equipped with absolute type filters on the exhaust. As an alternate, the vacuum exhaust may be vented outside the controlled work area.

8.3.3 Floors, walkways, etc., shall be damp mopped with water at least weekly. Walls and other surfaces shall be vacuumed and/or wiped with clean, low-lint cloths, or polyurethane wipers dampened with water, as required. A water solution of TSP (trisodium phosphate) may be used for stubborn soils but shall be followed by water-rinse mopping or wiping. Alternate cleaning solutions may be approved by the cognizant operating or surveillance organization.

8.3.4 In no case shall cleaning of floors be allowed while parts or assemblies are being installed or removed, or when a system or line is open.

8.4 SPECIAL GARMENTS

8.4.1 All personnel assigned to the controlled work area and all visitors shall wear approved clean room garments. These garments shall meet the requirements of Chapter 10. Smocks and caps are considered minimum apparel except for entry into a spacecraft. Spacecraft entry requires hoods, coveralls, and booties.

8.4.2 Special footwear is not required; however, mud-caked or dirty shoes shall not be allowed in the area. Shoes shall be cleaned with a mechanical shoe cleaner prior to entry, or tacky mats or other approved mats (such as magna mats) shall be utilized at the entry to the controlled work area.

8.4.3 Garments shall be changed weekly, as a minimum, or whenever they become visibly soiled.

8.4.4 Clean room garments must be removed in the change area prior to personnel leaving the controlled work area. In the event garments are worn outside the controlled work area, the person shall be barred from reentry until he has changed garments. Garments worn outside of the controlled work area or worn during contaminant-generating operations shall be considered contaminated and must be exchanged for clean garments.

8.5 OPERATIONS

8.5.1 Access to the controlled work area will be restricted to those personnel necessary for the operations in progress, quality assurance inspectors, and test or engineering personnel, as required.

8.5.1.1 Personnel with respiratory or skin diseases shall be excluded from the controlled area until such condition is corrected or cleared.

8.5.2 Records of particulate population or fallout are not required for controlled work areas; however, visual or wipe evidence of dust, dirt, or oils shall be reason for cessation of operations in the immediate area and cleaning of the affected area to a visibly clean condition. Upon completion of cleaning and acceptance by the cognizant quality group the operations may proceed. Articles subjected to the out-of-control conditions should be inspected to verify a visibly clean condition.

8.5.3 All cabinets, stools, benches, etc., shall be constructed of minimum particle-generating material.

8.5.4 All paper and paper products not necessary for the operation shall not be exposed within the controlled work area. Paper and paper products required for the operation shall be of a type treated to prevent particulate generation or shall be enclosed in a plastic bag except at times that exposure is required to read or sign off a particular operation.

8.5.5 Only approved, clean, low-lint wiping cloths or clean polyurethane wipers shall be used for cleaning operations.

8.5.6 Smoking, food, and beverages shall not be allowed in the controlled work area. Water fountains may be permitted if desired; however, paper drinking cups will not be allowed in the area.

8.5.7 All parts, equipment, tools, test fixtures, and apparatus shall be cleaned prior to entry into the controlled work area. The cognizant quality group shall verify that these are visibly clean prior to their entry.

8.5.8 Tools and fixtures shall be kept in drawers or stainless steel wire baskets or shall be covered when not in use. Tools shall not be kept in toolboxes, felt-lined drawers, or leatherette cases. Tools may be kept on clean polyurethane foam wipers.

8.5.9 All handtools shall be treated to resist corrosion and shall be constructed of minimum particle-generating materials. All tools shall be cleaned and verified visibly clean prior to entry to the controlled work area. The cognizant quality organization shall verify that tools are clean at time of use. Tools removed from the controlled work area or found visually soiled shall be cleaned and verified clean prior to reentry or use.

8.5.10 Oils, grease, or lubricants, other than those approved for specific applications, shall not be permitted in the controlled work area.

8.6 WORKPIECE OPERATIONS

8.6.1 Assembly, disassembly, modification, or repair to systems or subsystems, etc., which require that a system cleanliness level be maintained, shall be performed under localized clean conditions as specified in Chapter 14.

8.6.2 All surfaces, lines, parts, etc., opened due to part or assembly removal or system break-in, shall be protected with standard closures (metal plugs, caps, blind flanges) or covered with certified clean nylon or Aclar film. Film covers shall be securely sealed or taped to the unit. Plastic caps or plugs are not considered as acceptable closures.

8.6.3 Potential health or safety hazards associated with operations in the controlled work area shall be immediately referred to the cognizant management and safety organizations.

8.7 CONTAMINATION GENERATION CONTROL

8.7.1 Operations, equipment, etc., causing grease or oil deposits shall not be permitted. Hydrocarbon (oil, grease, smoke, etc.) generating equipment shall not be allowed in the controlled work area. Electrically operated equipment or other nonhydrocarbon-generating equipment may be used; however, they shall be verified clean by the cognizant quality organization prior to use.

8.7.2 Metal abraiding tools, such as pipe wrenches, pliers, knurled-jaw holding tools, vise grips, vises, etc., shall not be permitted in the controlled work area unless all the following conditions are met and verified prior to each use.

8.7.2.1 No alternate tool is available.

8.7.2.2 Tool is inspected for cleanliness prior to each use.

8.7.2.3 Jaws are padded with soft metal or other approved pad.

8.7.2.4 All lubricant is removed from tool prior to use.

8.7.3 Contaminant-generating operations such as sanding, grinding, chipping, drilling, welding, painting, etc.,

shall not be permitted in the controlled work area unless specifically approved by the cognizant quality organization. The following controls will then be exercised and monitored.

8.7.3.1 All tools and equipment used in the operation shall be visibly clean prior to entry into the controlled work area.

8.7.3.2 Areas and portions of the assembly adjacent to the contaminant-generating operation shall be securely covered to prevent accumulation or entrapment of particles.

8.7.3.3 Plastic or other approved material of sufficient size to catch particles generated shall be placed below the contaminant-generating operation.

8.7.3.4 Upon completion of the contaminant-generating operation the cover below the operation shall be thoroughly vacuumed, then removed. The surfaces and areas exposed by removal of the covers shall then be vacuumed. All adjacent areas, including walls and floors, shall then be vacuumed to the extent required to provide a visibly clean work area. Cleanliness shall be verified prior to further operations.

8.7.3.5 Personnel who performed the contaminant-generating operation must leave the controlled work area and change garments prior to their performance of other operations within the controlled work area.

CHAPTER 9
PERSONNEL CERTIFICATION

9.0 PERSONNEL CERTIFICATION

This chapter defines the minimum training and certification requirements for operational, technical, and clean room management personnel.

9.1 APPLICABILITY. The requirements of this chapter are applicable to all operational, quality, technical, engineering, and management personnel who, by normal assignment, are required to work in a clean room area more than 50 percent of the time. Special provisions are made for personnel who are currently assigned in these areas and for those personnel newly employed.

9.2 CURRENTLY ASSIGNED PERSONNEL. Personnel who are currently assigned and have satisfactorily performed their duties in the clean room area for a period exceeding 90 days may be issued provisional certification by the concurrence of the applicable quality and management organizations and the responsible MSC representative.

9.3 NEW EMPLOYEES. Newly employed personnel may be issued temporary certification to permit them entry to the clean room for a period not to exceed 90 days. Certification in specific clean room unit operations, as required, shall be issued to these personnel only after their successful completion of training as stipulated by this chapter.

9.4 CLEAN ROOM DISCIPLINES. The unit operations required in the operation of a clean room are listed to permit flexibility in the certification program. Personnel need only be certified in the operations that encompass their particular job responsibilities. The following chart indicates the unit operations and the personnel.

UNIT OPERATION	PERSONNEL REQUIRING CERTIFICATION
Entry to Clean Room	All Personnel (Note 1)
Precision Cleaning	Personnel Handling Cleaned Parts
Part Assembly	All Assembly Personnel
Testing (Functional)	All Test Personnel
Part/Item Sampling	All Sampling Personnel
Sample Analysis	Laboratory Personnel
Packaging	All Packaging Personnel
Janitorial Service	All Janitorial Personnel

NOTE 1: Personnel requiring entry to the clean area on a visitor or temporary basis shall be required to be knowledgeable in the basic operations of clean room entry or shall be instructed prior to entry. Such personnel shall be accompanied by, and be the direct responsibility of, an escort who is certified for clean room entry. Entry of visitors or temporary personnel shall be controlled by the appropriate clean room supervisor to prevent over-population or violation of the clean room integrity.

9.5 CERTIFICATION/RECERTIFICATION OF CURRENTLY EMPLOYED PERSONNEL. The provisional certification of clean room personnel currently employed as defined in section 9.2 shall be considered adequate certification where the employee continues to demonstrate proficiency in his operation. Recertification shall be comprised of a refresher course and written examination within each 12-month period.

9.5.1 REVOCATION OF CERTIFICATION. Provisional certification may be revoked for flagrant violation of established clean room/contamination control requirements or for continued violation of good work practices or clean room regulations.

9.6 CERTIFICATION OF NEW EMPLOYEES. New employees granted temporary certification for clean room entry shall only be granted such temporary certification after a thorough verbal indoctrination in clean room entry procedures, garment donning procedures, and clean room rules and regulations. Personnel having temporary certification shall be assigned to, and be the direct responsibility of, a certified operational, quality, technical, or supervisory person.

9.6.1 FORMAL CERTIFICATION. New employees shall be given a minimum of 2 hours formal training which shall encompass an introduction to contamination control disciplines, the applicable governing requirements, the purpose of contami-

nation control, and the possible effect of inadequate contamination control. This formal training shall be accomplished prior to the expiration of the 90-day temporary certification.

9.6.2 REVOCATION OF TEMPORARY CERTIFICATION. Temporary certification of a new employee may be revoked at the discretion of the operations or quality supervisor provided written justification for revocation is presented. Such certification shall be revoked if requested by the cognizant MSC representative as a result of his observation of serious clean room violations.

9.7 CERTIFICATION OF OTHER CLEAN ROOM DISCIPLINES. Certification of personnel in individual clean room operations shall be accomplished by the successful completion of a formal training program in each unit operation (as applicable) and the receipt of a passing grade on a written examination. Formal training for certification in these operations shall be conducted and/or approved by the MSC Quality Assurance Division prior to the initiation of training.

9.8 CERTIFICATION RECORDS. Records shall be maintained by the clean room operating organization which list each employee and the specific operations for which he is certified. A suggested format for this listing is shown in Table IV.

9.9 CERTIFICATION CERTIFICATE. Upon successful completion of the appropriate certification requirements, a certificate of certification may be issued. This certificate shall bear the signature and title of the authorized MSC Quality Assurance Certifying Representative.

9.9.1 REEXAMINATION REQUEST. The authorized certifying officer or the cognizant Division/Branch/Section Chief shall have the prerogative of requesting reexamination at any time there is reason to question the proficiency of the certified person.

9.10 CERTIFIED STATUS. Certified status may be attained as listed herein.

9.10.1 PREVIOUS CERTIFICATION. In the event that personnel have been previously certified, that person shall furnish the MSC Quality Assurance Certifying Representative with copies of certification test results, certifications, or any other data requested for proof of certification.

9.10.2 ADEQUACY OF CERTIFICATION. The MSC Quality Assurance Certifying Representative shall be responsible for verifying the adequacy of certificates. If the present certification is in accordance with MSC requirements, approval may be granted without further requalification.

9.10.3 CERTIFICATION RENEWAL. Certification of personnel shall include the necessary training (formal or on-the-job) followed by a test examination to ensure the proficiency of each individual. Personnel satisfactorily completing the necessary training and examinations shall be issued a certificate of performance as evidence of certification. The period of effectivity shall be specified on the certificate and the person concerned shall be recertified at the end of such periods through retesting or proof of proficiency.

CHAPTER 10
CLEAN ROOM GARMENTS

10.0 CLEAN ROOM GARMENTS

This chapter establishes the minimum requirements for the materials, construction features, laundering processes, and controls for clean room garments and accessories, including biologically clean garments.

10.1 GENERAL REQUIREMENTS. The following general requirements are minimum requirements.

10.1.1 GARMENT CONSTRUCTION. The garment shall cover the body adequately and shall incorporate adjustable collars and cuffs to give a snug fit. It may be fastened by either snaps, ties, or zippers. Garments selected must exhibit limited linting characteristics as defined below.

In situations where antistatic garments are required, garments having a surface resistivity approaching 11.0 log R units (log of resistivity per square unit of surface) shall be selected. This may be achieved by addition of an antistatic agent to the material.

10.1.1.1 FABRIC. Garments shall be of a 100 percent synthetic textile fiber such as Dacron or nylon.

10.1.1.1.1 COLOR. White or pastel.

10.1.1.1.2 WEAVE. Teffeta or herring-bone twill.

10.1.1.1.3 THREAD. 100 percent polyester continuous filament.

10.1.1.1.3.1 TYPE - Stranded, 200 denier minimum.

10.1.1.1.3.2 COLOR - Same as garment.

10.1.1.2 SEAMS. Closed, double-stitched, and free of loose threads.

10.1.1.3 POCKET. None.

10.1.1.4 SIZES. Garments shall be available in the following sizes:

10.1.1.4.1 Extra Small - 30-32

10.1.1.4.2 Small - 34-36

10.1.1.4.3 Medium - 38-40

10.1.1.4.4 Large - 42-44

10.1.1.4.5 Extra Large - 46-48

All smocks and coats shall be at least knee length and all coveralls shall have full length legs.

10.1.2 ACCESSORY CONSTRUCTION

10.1.2.1 HEAD COVERINGS. Head coverings may be any of the types described herein.

10.1.2.1.1 CAPS

10.1.2.1.1.1 Men - Surgeon's style with three position fasteners; small, medium, and large.

10.1.2.1.1.2 Women - Snood cap with drawstring.

10.1.2.1.2 HOODS AND FACE COVERS. Hoods shall completely cover head and neck except for face. Hood shall fit inside the neck of the coverall. These shall be available in the following sizes: small, medium, and large. A face mask shall completely cover beards or moustaches.

10.1.2.2 SHOE COVERINGS. The top of the shoe covers shall be made of the same material as the basic garment, be high enough to cover the coverall pants leg, and be secured to the pants leg by either a tie or snaps. All seams shall be turned inside and double stitched. The soles shall be made of skid-resistant plastic or other acceptable material. Shoe coverings shall be available in the following sizes: medium, large, and extra large.

10.1.2.3 SHOE SOCKS. Shoe socks shall be made of stretch nylon, one-size design, with coverage of leg to mid-calf.

10.1.2.4 GLOVES. Gloves shall be form-fitting, one-size design, and provide complete coverage. Each using agency should determine the least contaminant-generating material for their particular application.

10.1.2.5 WIPING CLOTHS. Cloths shall be lint free, single filament taffeta weave, and with edges hemmed with synthetic thread using a double-needle stitch.

10.2 LAUNDERING REQUIREMENTS

10.2.1 PROCESSING. All processing shall be conducted in facilities constructed and operated to assure class 100,000 or better clean room conditions as established by FED-STD-209A or Chapter 6.

10.2.2 CLEANING TECHNIQUES. Cleaning may be carried out by water washing or dry cleaning performed under approved clean room techniques. Either method or a combination of the two is acceptable as long as particulate content is held within acceptable limits.

10.3 INSPECTION. Inspection of clean room garments shall be accomplished as described herein.

10.3.1 SAMPLING. Two percent of each shipment shall be checked to assure that garments meet particulate requirements listed below. Particulate determination shall be conducted in an environment equal to or better than the environment where the garment was cleaned. Points of garments to be checked shall be in accordance with or a method similar to that established by ASTM F51-65T, or T. O. 00-25-203.

10.3.2 INSPECTION PERSONNEL. All personnel in the inspection area shall be garbed in coveralls, hoods, and shoe covers, and shall wear gloves during handling of garments.

10.3.3 VISUAL INSPECTION. Each garment and accessory shall be inspected for needed repairs, missing snaps, and broken zippers. Any garment or accessory showing breakdown

of fabric, as evidenced by loose fiber ends protruding from the surface, shall also be rejected.

10.4 ACCEPTANCE CRITERIA AND LIMITS. The minimum acceptance criteria and limits shall be as established by this document.

10.4.1 PARTICULATE. The maximum permissible concentration of particles and fibers per square foot of fabric surface shall not exceed 5000 particles 5 microns and larger with a maximum of 25 fibers (filtered air is drawn through five 0.01 square foot areas of a single thickness of the garment fabric at a rate of 14 liters per minute for 1 minute per area). Method of sampling shall be in accordance with or a method similar to that established by ASTM F51-65T or T. O. 00-25-203. Alternate methods with higher flow rates and particle and fiber concentrations may be utilized if approved by MSC.

10.4.2 PARTICLE COUNTING METHOD. Microscopic counting of particles shall be in accordance with or a method similar to that established by ASTM F51-65T or T. O. 00-25-203.

10.4.3 HYDROCARBONS. Sample garments shall have no visible hydrocarbons such as oil stains or grease.

10.4.4 CERTIFICATION. Certification showing evidence of compliance with these requirements shall be submitted by the supplier with each shipment.

10.5 PACKAGING. The packaging of clean room garments shall be as described by 10.5.1.

10.5.1 INTIMATE PACKAGING. All garments shall be packaged individually in a polyethylene bag which shall be hermetically sealed in the clean room prior to exposure to an uncontrolled environment. All garments biologically cleaned shall be packaged in one to three mil polyethylene.

10.6 BIOLOGICALLY CLEAN GARMENTS. All garments to be biologically cleaned shall meet the construction requirements of 10.1 and the cleaning and certification requirement of 10.2 through 10.5.1, in addition to the requirements stipulated herein.

10.6.1 STERILANTS. ETO (ethylene oxide) shall be used to sterilize the garments. To insure safety in the use of the ETO the sterilant composition shall be as follows:

12 percent ETO
88 percent Dichlorodifluoromethane

10.6.2 STERILIZED CONDITIONS. The following sterilizing conditions shall be considered standard.

10.6.2.1 Total time of cycle - 4.5 hours, to include preconditioning, final chamber vacuum, and the relief of the final vacuum with filtered air to atmospheric pressure.

10.6.2.2 Temperature of chamber - 49 to 60°C. (120 to 140°F.)

10.6.2.3 Humidity of gas in chamber - 30 to 60 percent.

10.6.2.4 Pressure inside chamber - 5 to 10 psig (Depends upon quantity of ETO used)

10.6.2.5 Quantity of ETO required - 450 mg./l. 850 mg./l.

10.6.2.6 Vacuum - 26 to 27 inches Hg.

10.6.3 STERILIZING EQUIPMENT. The sterilizing equipment shall consist of a sterilizing vessel capable of containing the garments during the sterilization cycle. Auxiliary equipment to insure sterilizing conditions shall also be supplied.

10.6.4 STERILIZING CYCLE. The following is a typical sterilizing cycle.

10.6.4.1 A preconditioning phase is performed in which an initial vacuum of 26 to 27 inches Hg is drawn on the preheated chamber and the load is humidified.

10.6.4.2 The ETO mixture is introduced into the chamber via a heat exchanger until the preselected pressure is reached, at which time the gas flow is discontinued.

10.6.4.3 The exposure period is started (usually 4 hours).

10.6.4.4 Following the exposure period, the gas is exhausted from the chamber and a final vacuum of 25 inches Hg is drawn.

10.6.4.5 The chamber is returned to atmospheric pressure by introducing filtered air (0.3 micron filters) to prevent recontamination of the load.

10.6.5 OTHER STERILIZING CYCLES. Other sterilizing cycles may be approved by MSC after proof of sterilization using spore strips has been provided.

10.6.6 CERTIFICATION. Certification shall conform to 10.4.4.

10.7 OUTER PACKAGING. The method of final packaging, i.e., overbagging, shipping drums, etc., is not mandatory; however, the method selected shall provide protection for the inner bags to reduce the possibility of tearing or otherwise exposing the garments during shipment.

10.7.1 The final packaging of bioclean garments shall clearly identify the packages as containing biologically clean garments.

CHAPTER 11
PRECISION CLEANING

11.0 PRECISION CLEANING

This chapter describes general methods of cleaning spacecraft and components. The constraints implied by cleaning and techniques of cleaning are covered. The cleaning methods and cleaning materials to be employed in the decontamination and cleaning of parts and components for use in spacecraft fluid systems are also delineated.

11.1 GENERAL REQUIREMENTS. Parts and equipment whose service requirements entail specified precision cleanliness levels shall be cleaned in conformance with this chapter and assembled and packaged in a suitably clean environment. When individual parts of an assembled component have not been cleaned prior to assembly, the assembled component shall be rejected and the cleaning procedures, disassembly, rework, and retest (if applicable) shall be specified by MRB (Material Review Board) disposition. A qualified engineer experienced in contamination control should participate in the MRB. Cleaning or disassembly operations on precision components which might affect tolerances or impair calibration shall be performed only under the supervision of personnel qualified in the handling, calibration, and/or assembly of the components. Each part or component to be cleaned shall be controlled by a detailed procedure which shall be in accordance with the requirements of this chapter. The cleaning procedure established for each part or component shall be compatible with design configuration. Each item requiring precision cleaning shall be precleaned prior to precision cleaning.

11.2 SELECTION OF CLEANING FLUIDS. Selection shall be consistent with the contaminants to be removed, the materials of construction of the part or component to be cleaned, and the level of cleanliness desired. All such fluids shall be certified prior to use. Acceptance requirements for cleanliness must be adequate for meeting the design requirements of the part or component relative to the intended system use and the system cleanliness level. Cleaning methods must be nondetrimental to the materials of construction and/or the mechanical design requirement of the part or component. Application of each cleaning solution must be restricted to usages where problems subsequent to cleaning will not occur as a result of the application, e.g., corrosion from entrapped cleaning fluids, corrosive cleaning fluid residues, etc.

Contaminated items which cannot be cleaned because of special tooling or calibration requirements shall be returned to the manufacturer or other disposition taken as required.

All steps in any procedure must progress in an uninterrupted series of operations through the final rinse and drying operation. Precautions must be taken to protect systems or parts after final rinsing and drying until inspection, assembly, and/or packaging. Cleanliness levels and the clean room class required shall be selected from the levels and classes defined by Tables I, II, and III.

11.3 GARMENTS. Clean room attire as prescribed in Chapter 10 shall be worn during that portion of the precision cleaning operation that is performed in a clean room, or clean work station.

11.4 PRECLEANING PROCEDURES

11.4.1 MECHANICAL DESCALING. This cleaning method removes contaminants by abrasive action. This method shall be used only when contaminants generated by this abrasive action can be removed or when physical damage to the item being cleaned will not occur.

Mechanical descaling may be accomplished by brushing, shot peening, grit blasting, vapor honing, tumbling, or grinding. Surfaces which contain scale and/or oxides and all steel or stainless steel welds which will be exposed to gas or liquid and are accessible shall be thoroughly cleaned with a stainless steel wire brush, grinder, or abrasive material. Carbon steel surfaces may be shot blasted. The use of the same stainless steel wire brush for carbon steel and stainless steel shall be forbidden. Material to be used for abrasive cleaning stainless steel surfaces shall contain no ferrous or ferric materials. Internal surfaces of pipe may be cleaned by a "go-devil" type of device with a grinder of 150 grit abrasive or finer. All loose dirt, abrasive, or scale shall be completely removed from components by vacuum cleaning, blowing, brushing, or flushing with clean water. Components whose welds are not accessible for mechanical descaling shall be descaled by pickling. All piping will be further descaled by acid pickling.

11.4.2 VAPOR DEGREASING. Soluble organic contaminants (e.g., oils, greases, hydrocarbon fuels, etc.) are readily removed by vapor degreasing.

Parts to be vapor degreased shall be processed in a standard commercial degreaser or degreasing vapors shall be blown into the component parts so that the vapor will condense on and properly degrease all surfaces. The operation of the commercial vapor degreaser shall be in accordance with the manufacturer's recommendations.

11.4.3 SOLVENT DEGREASING. Soluble organic contaminants are removed by organic solvent cleaners. These solvents are also used for final system flushing. Not only are soluble hydrocarbons removed but also particulate contaminants are removed by becoming entrained in the flush fluid.

If both oils and preservatives are present on a component, solvent degreasing is required followed by detergent degreasing. Components may be steam cleaned prior to solvent degreasing. Components to be solvent degreased shall be immersed in or partially filled with trichloroethylene, perchloroethylene, chlorothene, or other chlorofluorocarbons. Components shall be rolled or rocked to be sure that the solvent washes all surfaces requiring degreasing.

11.4.4 DETERGENT DEGREASING. Alkaline cleaners and detergents are used for removal of organic and inorganic contamination which can be removed by solution or emulsification (e.g., oils, fat, shop soils, grease, etc.).

Components shall be degreased in a solution of detergent and water. Surfaces of the component should be swept with a soft nylon brush. Detergent degreasing can also be accomplished in an ultrasonic cleaner. Rinsing shall be done under tap water followed by demineralized water. The components shall then be oven dried.

11.4.5 ALKALINE DEGREASING. Components may be degreased with commercial alkaline cleaners. The components shall be filled, immersed, sprayed, or scrubbed with the particular alkaline cleaner in accordance with manufacturer's recommendations.

11.4.6 ACID PICKLING. Acid cleaners are to be used to remove contamination not soluble in other solutions (e.g., weld scale, corrosion products, oxide film, etc.).

Components which contain rust, scale, weld splatter, or other foreign material after degreasing, may be pickled. Mechanical cleaning shall not be performed after pickling.

11.4.6.1 STAINLESS STEEL. Acid pickling effectively loosens corrosion from stainless steel. All parts such as those found in valves and filter elements that contain materials which may be damaged during pickling shall be removed to prevent their damage. Prior to pickling, the component shall be thoroughly flushed with clean water. The particular pickling agent shall be used in accordance with manufacturer's recommendations.

11.4.6.2 CARBON STEEL. Carbon steel shall be pickled in a bath of either inhibited hydrochloric acid or phosphoric acid, or descaling may be accomplished by using alkaline solutions. The pickling or alkaline procedures shall be followed immediately by flushing with demineralized water. Within 5 minutes after removal from the pickling acids, a rust-inhibiting procedure shall be initiated. If alkaline solutions are used for descaling, this step is not required.

11.4.6.3 ALUMINUM AND ALUMINUM ALLOYS. Aluminum and aluminum alloys shall be pickled as required. After alkaline cleaning, rinsing shall be done immediately with warm water to prevent dry-on. The final rinse shall be made with deionized water.

11.4.6.4 COPPER AND COPPER ALLOYS. Copper and copper alloys shall be pickled. Provision shall be made to assure that acid cleaning solutions shall be free of iron. Ammoniacal solutions shall not be used for cleaning brass. The final rinse for copper and copper alloys shall be made with deionized water.

11.4.7 PASSIVATION. All components shall be rendered passive. Passivating solutions are supplementary treatments to acid, alkaline, and mechanical cleaning to prevent corrosion.

Care shall be taken to prevent damage to passivated surfaces from scratching, nicking, abrasion, etc.

Passivation should not be confused with conversion films or other protective film processes.

11.4.8 DRYING. Drying shall take place immediately after the final rinse using nitrogen gas, oven drying, air drying, or vacuum drying.

11.4.9 INSPECTION METHODS. Following precleaning, the inspection methods defined herein shall be used as required to determine item cleanliness.

11.4.9.1 ULTRAVIOLET LIGHT (BLACK LIGHT) Components shall be inspected with an ultraviolet light source of 3200 to 3800 Angstroms for contaminants. Any evidence of fluorescent materials shall be cause for recleaning.

Ultraviolet light inspection will not detect common hydrocarbon fuels, some silicone greases, MIL-H-5606B hydraulic oil, thread sealants, and fluorocarbon greases commonly found as contaminants. Ultraviolet light will cause the following commonly used materials to fluoresce: most water soluble machining and cutting oils, some lints, molybdenum disulfide, MIL-L-6086B lubricating oil, MIL-G-4343B grease (DC-55), silicates from cleaning solutions, and some metallic compounds.

11.4.9.2 VISUAL OBSERVATION. Visual observation is the most common inspection method. It is used to detect the presence of substances such as oils, greases, preservatives, corrosion products, weld slag and scale, shop or other dirt, and other materials foreign to the item. Magnification lenses may be used to further identify suspected contaminants.

All equipment, pipes, and components shall be examined for evidence of corrosion products, metal chips, casting, molding and/or forging scale, weld scale, oil, grease, paints, preservatives, decals, and other contamination or foreign matter which constitutes a reactive or

functional hazard to the system. Any visual contamination shall be cause for recleaning. Observations must be made with the unaided eye (corrected vision accepted) and white light of sufficient intensity to illuminate the area being inspected. No magnification lenses are to be used except to further identify a contaminant. Visual observation is limited to use where the surfaces to be inspected are accessible. (This does not preclude the use of borescopes or other similar devices.)

11.4.9.3 WIPE TESTS. Wipe tests may be used to detect oily residues that may not be visible because of configuration, color, or other characteristics of the item being inspected.

The desired surface to be inspected is lightly rubbed with a lint-free medium. The medium must be visually observed for the presence of oils and debris. Care should be taken so as not to rub too hard on most surfaces. As an example, aluminum may abrade and thereby soil the wiping medium which would erroneously indicate a contaminated surface. When the wiping medium is to be extracted with solvent to determine hydrocarbon contamination, the area being wiped must be calculated and the amount of extraction solvent measured. A hydrocarbon determination must be made as a blank on the medium and the blank should be subtracted from the sample hydrocarbon determination.

11.4.9.4 WATER BREAK TEST. The water break test is used to detect oily residues that may not be visible because of configuration, color, or other characteristics of the item being inspected.

An atomizer with distilled water is used to perform this test. The surface to be checked will be made accessible preferably in the horizontal face-upward position. The area to be tested is sprayed sufficiently to completely cover the surface with droplets or a thin layer of water. The presence of predominant droplets on the surface is the indication of the possible presence of oily hydrocarbons. There are nonhydrocarbon materials that will cause water to form droplets on a surface. Also, there are materials which are hydrocarbons that will not cause water to form droplets.

NOTE: DECONTAMINATION. Parts used in fuel or oxidizer systems, or otherwise exposed to fuel or oxidizer, must be decontaminated to obtain a surface condition that is safe for subsequent handling or cleaning and free of corrosive residue. Water immersible parts shall be soaked in clean water followed by thorough rinsing. Nitrogen shall be used for drying. Before nonwater immersible parts (gages, transducers, and all electromechanical devices) are decontaminated, the component must be encased and sealed with tape in such a manner that only the system media entry or exit ports of the component are exposed. The interior of ports and sensing chambers or compartments shall be flushed with deionized water. Warm dry nitrogen shall be used for drying.

11.5 FINAL CLEANING

11.5.1 FINAL (PRECISION) CLEANING. All systems and components shall only be subjected to a clean room environment following general cleaning as heretofore described. Clean rooms or clean work stations are described in FED-STD-209A and Chapters 6 and 7. Those items scheduled for cleaning in a clean room environment shall be flushed or wiped with a suitable cleaning solution or solvent and/or vacuum cleaned or blown off with clean, dry air to prevent entry of gross contaminants into clean rooms. Solvent cleaning or blowing an item with clean air may be omitted when these procedures are detrimental.

Final cleaning shall be accomplished using solvents or other cleaning solutions (such as detergents) previously filtered to remove particulate and other contaminants and suitably low in NVR and particulate consistent with the cleanliness levels to be achieved. Special final cleaning processes may be required for specific equipments such as certain umbilical hoses, or items containing elastomers.

11.5.2 RINSE TEST. Unless otherwise specified, following final cleaning, each cleaned item shall be rinsed using a minimum of 100 ml. of unused filtered solvent as in final cleaning for each square foot of critical surface tested. A 500 ml. sample shall be the minimum used in any case. Rinsing shall be accomplished by agitation, sloshing, or by spraying the test solvent over the critical surface in such manner as necessary to obtain a reliable rinse test solution. The test solvent shall be drained immediately to prevent particle redeposition on the test surface. Clean components should be placed in the inner packaging wrap (not sealed) during the particulate/NVR residue determination to preclude contaminating the component.

11.5.2.1 MINIMUM SAMPLE VOLUME. A minimum sample volume of 500 ml. is required to assure dispersion of the generated particulate and aids in preventing the rejection of a sample for sampling operation particulate. Small parts shall be grouped to make a minimum surface area of one square foot. In the event sufficient parts are not available, the individual item may be considered as one square foot.

11.6 CLEANING METHODS AND MATERIALS. The requirements for cleaning methods and materials used on spacecraft parts, systems, or components shall be as described herein unless otherwise specified by contractual documentation, or approved by MSC or its designated representative.

11.6.1 ENVIRONMENTAL REQUIREMENTS FOR PARTS/COMPONENTS. Excluding precleaning, all cleaning and inspection operations shall be accomplished within a clean room or clean work station per Chapters 6 and 7 or FED-STD-209A. The clean room level shall be consistent with the cleanliness level requirements of the parts/components.

11.6.1.1 HANDLING OF COMPONENTS. Neoprene rubber gloves shall be worn during all solvent cleaning operations. Clean, white nylon gloves shall be worn when handling cleaned components. Care shall be taken not to recontaminate components.

11.6.2 CLEANING STAINLESS STEEL PARTS. Cleaning of stainless steel parts may be as follows. Various stainless steel alloys may require variations in the cleaning methods.

11.6.2.1 ALKALINE CLEANING. Alkaline clean with a suitable alkaline cleanser using nylon brushes as required. Immersion time, temperature, and concentration shall conform to manufacturer's recommendations. Rinse with hot (150° to 180°F.) tap water followed by a rinse with high purity water conforming to MSC-SPEC-C-20A. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.2.2 FINAL CLEANING. Ultrasonically clean with Precision Cleaning Agent (MSFC-SPEC-237A) for 2 to 5 minutes or spray rinse with the agent for approximately 1 minute.

11.6.3 CLEANING NONPLATED ALUMINUM PARTS. The cleaning of nonplated aluminum parts shall be accomplished as follows.

11.6.3.1 VAPOR DEGREASING. Vapor degrease with trichloroethylene conforming to MIL-T-27602. Keep parts in degreaser until condensation ceases. Alternately, parts may be solvent degreased with cold trichloroethylene or Precision Cleaning Agent (MSFC-SPEC-237A).

11.6.3.2 ALKALINE CLEANING. Alkaline clean with a suitable alkaline cleanser for aluminum. Immersion time, temperature, and concentration shall conform to manufacturer's recommendations. Rinse with hot (150° to 180°F.) tap water. Rinse with high purity water conforming to MSC-SPEC-C-20A. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.3.3 FINAL CLEANING. Ultrasonically clean with Precision Cleaning Agent (MSFC-SPEC-237A) for 2 to 5 minutes or spray rinse with the agent for approximately 1 minute.

11.6.4 CLEANING NONMETALLIC PARTS. The cleaning of nonmetallic parts shall be as follows. For the purpose of this document, nonmetallic materials incude natural rubber, Teflon, nylon, Kel-F, polyethylene, and any other plastic or synthetic rubber materials.

CAUTION: Determine that the material to be cleaned will not be adversely affected by the cleaning solution.

11.6.4.1 CLEANING. Decontaminate using cold tap water flush until pH of effluent is within one-half pH unit of influent. Detergent clean with a biodegradable, nonionic detergent using nylon brushes as necessary. Spray rinse with hot (150° to 180°F.) tap water followed by a rinse with deionized water that has a minimum specific resistance of 50,000 ohms. Dry with hot (120°F. maximum) nitrogen gas (MSFC-SPEC-234A).

11.6.5 CLEANING NEWLY WELDED STAINLESS STEEL PARTS. Newly welded stainless steel parts shall be cleaned as follows.

11.6.5.1 PRECLEANING. Mechanically clean with nylon or stainless steel wire brushes using a suitable general purpose alkaline cleaner as necessary. Do not use steel brushes on machined surfaces. Rinse with hot (150° to 180°F.) tap water. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.5.2 VAPOR DEGREASING. Vapor degrease with trichlorethylene conforming to MIL-T-27602. Keep parts in degreaser until condensation ceases. Alternately, parts may be solvent degreased with cold trichloroethylene or Precision Cleaning Agent (MSFC-SPEC-237A).

11.6.5.3 ALKALINE CLEANING. Alkaline clean with a suitable general purpose alkaline cleanser and use nylon or stainless steel brushes as required. Immersion time, temperature, and concentration shall conform to manufacturer's recommendations. Rinse with hot (150° to 180°F.) tap water. Pickle for 5 to 10 minutes in a

solution at room temperature made up (by weight) of 3 to 5 percent hydrofluoric acid conforming to O-H-795, balance tap water. Rinse with cold tap water. Passivate with a suitable stainless steel surface conditioner. Immersion time, temperature, and concentration shall conform to manufacturer's recommendations. Rinse with cold tap water followed by a rinse with deionized water that has a minimum specific resistance of 250,000 ohms. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.5.4 FINAL CLEANING. Ultrasonically clean with Precision Cleaning Agent (MSFC-SPEC-237A) for 2 to 5 minutes or spray rinse with the agent for approximately 1 minute.

11.6.6 CLEANING PLATED OR COATED ALUMINUM PARTS. Plated or coated aluminum parts shall be cleaned as follows.

11.6.6.1 SOLVENT DEGREASING. Solvent degrease with cold trichloroethylene conforming to MIL-T-27602 or Precision Cleaning Agent (MSFC-SPEC-237A) for a maximum of 1 minute. Solvent degreasing shall be accomplished with clean, lintless wiping cloths. Rinse with cold tap water.

11.6.6.2 DETERGENT CLEANING. Detergent clean with a suitable detergent cleaner using clean, lintless wiping cloths. Exposure time, temperature, and concentration shall conform to manufacturer's recommendations. Rinse with hot (140°F. maximum) tap water, followed by a rinse with deionized water that has a minimum specific resistance of 50,000 ohms. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.6.3 FINAL CLEANING. Ultrasonically clean with Precision Cleaning Agent (MSFC-SPEC-237A) for 1 minute maximum or spray rinse with the agent for 1 minute maximum.

11.6.7 CLEANING ALUMINUM OR STAINLESS STEEL PARTS WITH NONREMOVABLE NONMETALLIC INSERTS. Cleaning items of this type shall be as follows.

11.6.7.1 DETERGENT CLEANING. Detergent clean with a suitable detergent cleaner using nylon brushes sparingly on all surfaces. Immersion time, temperature, and concentration shall conform to manufacturer's recommendations. Spray rinse with hot (140°F. maximum) tap water followed by a rinse with deionized water that has a minimum specific resistance of 50,000 ohms. Dry with hot (120°F. maximum) nitrogen gas (MSFC-SPEC-234A).

11.6.7.2 FINAL CLEANING. Ultrasonically clean with Precision Cleaning Agent (MSFC-SPEC-237A) for 1/2 minute maximum or spray rinse with the agent for 1/2 minute maximum. (See caution in 11.6.11 concerning the nonmetallic inserts.)

11.6.8 CLEANING SMOOTH BORE HOSES AND TUBING. Smooth bore hoses and tubing shall be cleaned as follows.

11.6.8.1 PRECLEANING. Examine hoses or tubes for evidence of kinks, bends, or thread damage. Decontaminate by immersion or flush rinsing with cold tap water until pH of effluent is within one-half pH unit of influent.

11.6.8.2 DETERGENT CLEANING. Detergent clean exterior surfaces of hoses or tubing with a nonionic biodegradable detergent cleaner using nylon brushes as required. Exposure time, temperature (not to exceed 140°F.), and concentration shall conform to manufacturer's recommendations. Rinse with tap water. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A). Carefully clean end fittings of hoses and tubes with Precision Cleaning Agent (MSFC-SPEC-237A) using nylon brushes as required. Care must be taken to assure that the solvent does not contact the hose. Install adapter fitting and connect hose or tube to be cleaned to the pump discharge line. Verify that the hose or tubing diameter is equal to or greater than the I.D. of the flush pump discharge hose; install a restrictor fitting in the downstream end of the hose or tube being cleaned. This provides back pressure so that cleaning and rinsing solutions will contact all interior surfaces.

11.6.8.2.1 CLEANING OF HOSE ASSEMBLIES. Flush hose with a non-ionic biodegradable detergent cleaner for 5 to 15 minutes. Change flush pump suction to deionized water that has a minimum specific resistance of 50,000 ohms and flush for 1 to 2 minutes. Detach hose from flush pump discharge hose and remove all adapter fittings. Thoroughly rinse end fittings of hose with the deionized water. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A). Dry in heated (120° to 140°F.) vacuum chamber for 25 to 30 minutes at maximum vacuum.

11.6.8.3 FINAL CLEANING (HOSE AND TUBE ASSEMBLIES). Spray rinse exterior and interior of end fittings with deionized water. Flush rinse small hoses or tubes with 10 micron filtered deionized water. Fill and drain large hoses or tubes with 10 micron filtered deionized water. The flow of water at the downstream end of the hose or tube shall be restricted as necessary to provide fluid contact to all interior surfaces of the hose or tube.

11.6.8.4 FINAL RINSE AND CLEANING. Flush rinse small hoses or tubes with 0.8 micron deionized water. Fill and drain large hoses or tubes with 0.8 micron filtered water. The flow of water at the downstream end of the hose or tube shall be restricted as necessary to provide fluid contact with all interior surfaces of the hose or tube. After completion of the final rinse, continue the rinse and collect 100 ml. of water per square foot of interior surface of the hose or tube. Dry interior surfaces and end fittings with 10 micron absolute filtered hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.9 CLEANING TRANSDUCERS, TEMPERATURE SENSORS, AND FLOWMETERS. Transducers, temperature sensors, and flowmeters shall be cleaned as follows.

11.6.9.1 PRECLEANING. Clean exterior with clean, lintless cloth dampened with Precision Cleaning Agent (MSFC-SPEC-237A). Encase the item in a polyethylene bag and tape seal so that only the sensing part(s) or surfaces are exposed. Using a wash bottle filled with distilled water having a minimum specific resistance of 50,000 ohms, flush interior of transducers and flush exterior sensing surfaces of temperature sensors. Use fill-and-drain method to flush fluid passageways of flowmeters. Flush items until effluent water is visibly clear of discoloration and particles and the pH is within one-half pH unit of influent. Dry with hot (140°F. maximum) nitrogen gas (MSFC-SPEC-234A) by holding the gaseous nitrogen wand at a minimum distance of 1 foot from the item to provide ventilation of the item only and to prevent pressure buildup in the sensing chamber or bending of small diameter temperature sensor probes.

11.6.9.1.1 SOLVENT CLEANING. Repeat, using Precision Cleaning Agent (MSFC-SPEC-237A) instead of water, and continue flushing until effluent is visibly clear of discoloration and particulates. Examine the sensing chambers of transducers for visible contamination on the diaphragm or threads. Examine temperature sensors for visible contamination on threads and sensing surfaces. Examine the fluid passageways, vent holes, vanes, etc., for visible contamination. If visible contamination is evident, continue flushing. Do not introduce a brush, probe, thread chaser, or any device, metal or plastic, into the sensing chamber of a transducer to dislodge contaminants from the sensing chamber or from the sensing port threads. Dry with hot (140°F. maximum) nitrogen gas (MSFC-SPEC-234 A) by holding the gaseous nitrogen wand at a minimum distance of 1 foot from the item to provide ventilation of the item only and to prevent pressure buildup in the sensing chamber or bending of small diameter temperature sensor probes.

11.6.9.2 FINAL CLEANING. Flush sensing chambers, probes, threads, or fluid passageways and surrounding areas with Precision Cleaning Agent (MSFC-SPEC-237A) that has been passed through a 10 micron absolute filter. Continue flushing for 1 minute or until areas and effluent are visibly clear of contamination. Repeat, using Precision Cleaning Agent (MSFC-SPEC-237A) that has been passed through a 2 micron absolute filter.

11.6.9.2.1 DRYING. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A), by holding the drying wand at a minimum distance of 1 foot from the item to provide ventilation of the item only and to prevent pressure buildup in the sensing chamber or bending of small diameter temperature sensor probes.

11.6.10 CLEANING TITANIUM PARTS. Titanium parts shall be cleaned as described herein and the materials used for titanium parts shall be certified as compatible with titanium.

11.6.10.1 HANDLING OF PARTS. Neoprene rubber gloves shall be worn during all solvent cleaning operations. Clean, low-lint, white nylon gloves shall be worn when handling parts of cleaned systems. Care shall be taken not to recontaminate systems.

11.6.10.2 PRECLEANING. Decontaminate by flushing with cold tap water until pH of effluent is within one-half pH unit of influent. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A). Flush with cold trichloroethylene conforming to MIL-T-27602. Flush with hot (150° to 180°F.) tap water followed by a flush with deionized water that has a minimum specific resistance of 50,000 ohms. Dry with hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A).

11.6.10.3 FINAL CLEANING. Flush with Precision Cleaning Agent (MSFC-SPEC-237A) that has been passed through a 10 micron absolute filter. Continue flushing for 1 minute or until effluent is visibly clear of contamination. Repeat this flush using Precision Cleaning Agent (MSFC-SPEC-237A) that has been passed through a 2 micron absolute filter.

11.6.11 CLEANING PLASTIC, GLASS, AND ELASTOMERIC MATERIALS. Cleaning of these materials may be accomplished using the methods described herein.

CAUTION: Organic solvents such as carbon tetrachloride, isopropyl alcohol, thinners, strippers, and similar materials shall not be used on transparent acrylic plastic materials.

11.6.11.1 GENERAL REQUIREMENTS

11.6.11.1.1 Plastic materials shall not be rubbed with dry cloths or sponges.

11.6.11.1.2 Rinse sponges or cloths as required to remove accumulated soils.

11.6.11.1.3 Precision optical surfaces require special cleaning procedures and shall not be cleaned in accordance with these requirements.

11.6.11.2 Cleaning of plastic, glass, and elastomeric materials shall be as shown on page 64.

CLEANING OF PLASTICS, GLASS, AND ELASTOMERIC MATERIALS

MATERIAL TYPE	OPERATION	CLEANING MATERIALS
Acrylic plastics and elastomers, glass, fluorinated plastics, and laminated or molded plastics (not including phenolics)	Wipe Clean	Approved wipe dampened with general purpose detergent (10% solution) with demineralized water
	Wipe Rinse	Approved wipe dampened with demineralized water
	Dry	Low flow filtered dry air
Glass, fluorinated plastics, and molded or laminated plastics (not including phenolics)	Solvent Wipe Clean	Approved wipe dampened with MEK, Trichloroethylene, precision cleaning agent, trichlorotrifluoroethane inhibited (Instrument grade)
	Dry	Air dry
Phenolic plastics including laminated and nonlaminated	Solvent Wipe Clean	Approved wipe dampened with MEK
	Dry	Air dry

11.7 INSPECTION. All parts shall be visually inspected after completion of precleaning and prior to entering the clean room in accordance with 11.4.9 through 11.4.9.4 as applicable. Final inspection of precision cleaned parts shall be made upon completion of the final cleaning operation. This inspection shall be in accordance with 11.5 through 11.5.2.1 as applicable.

11.7.1 COMPONENT CLEANLINESS. The cleanliness of the components shall be verified by a rinse test according to 11.5.2. The effluent of the rinse test shall be examined for particulate matter by the particle count method and the NVR of the solvent rinse test shall be determined in accordance with Chapter 13.

11.8 FINAL PACKAGING. Packaging shall be accomplished in accordance with the requirements of Chapter 12.

CHAPTER 12
PRECISION CLEAN PACKAGING

12.0 PRECISION CLEAN PACKAGING REQUIREMENTS

This chapter establishes the material, material cleanliness, packaging methods, and the package sealing requirements for parts and components that have been precision cleaned.

12.1 PACKAGING MATERIALS CLEANLINESS. The minimum surface cleanliness requirements for packaging materials to be used for the packaging of precision cleaned components or any material which will be used for the environmental packaging of, and be in intimate contact with, precision cleaned surfaces, shall be subject to the requirements of this chapter.

12.1.1 PROCUREMENT REQUIREMENTS. As a minimum all packaging material shall have been precision cleaned to or procured at least one level cleaner than the item to be packaged (i.e., items cleaned to a Level 4 should be packaged in a material cleaned to Level 3). When Level 1 cleanliness is required, only nylon films shall be used as nylon is the only film capable of retaining this level. Bags, sheeting, tubing, roll stock, and other cleaned film shall be overwrapped with a second bag of clean, 4 to 6 mil, antistatic polyethylene. Roll stock shall be wound on clean cores made from nondusting plastic or metal. Closures, seals, etc., shall be overwrapped and sealed in film cleaned to Level 3 of Table I.

12.1.2 ENVIRONMENTAL CONTROL. All processing and inspection operations shall be accomplished within a clean work bench as defined in Chapter 7 which is consistent with or cleaner than the packaging material being processed and inspected. Clean, white gloves conforming to the requirements of Chapter 10 shall be worn while packaging materials are handled inside the clean room. Care shall be taken not to contaminate packaging materials.

12.1.3 GENERAL INSPECTION REQUIREMENTS. Packaging materials shall be examined and tested to determine compliance with the requirements of this chapter.

NOTE: Plastic films, including ordinary (nonantistatic) polyethylene, generate large electrostatic charges when handled, rubbed, or when one surface is separated from

another as in opening a bag or unrolling a sheet of film. These charges can cause attraction of large quantities of airborne particles to the surfaces of such film unless precautions are taken to minimize exposure of clean film surfaces to the clean room atmosphere prior to testing for verification of cleanliness level.

12.1.4 VISUAL INSPECTION REQUIREMENTS. No evidence of oil, grease, water, solvents, paints, ink, dirt, metal chips, decals, preservatives, or other foreign matter shall be permitted on either the external surfaces or the internal surfaces of intimate packaging materials or the internal surfaces of the overwrap packaging when inspection is made with the unaided eye.

12.1.5 ULTRAVIOLET LIGHT INSPECTION. The external and internal surfaces of metallic closures shall be examined for evidence of fluorescence under ultraviolet light. Fluorescent areas that continue to fluoresce after hand wipe cleaning with solvent shall not be rejected.

12.1.6 SAMPLING FOR RINSE TEST VERIFICATION OF CLEANLINESS LEVEL. A minimum of one percent of the procured bags and a minimum of one sample from each roll of sheet or tubing stock shall be sampled in accordance with the following requirements.

12.1.6.1 PREPARATION. The bag shall be heat-sealed across the open end. Using surgical scissors or another extremely sharp blade (to minimize particle generation when cutting) one corner of the bag shall be cut off so that an opening not over 3/4 inch in length is created. Plastic tubing for precision packaging applications shall be sealed at both ends of a length to give an inside test area of approximately 1 square foot and sampled for rinse test as for bags. Plastic film (flat roll stock) shall be cut carefully with surgical scissors or other sharp blade to a length of 12 inches. The section shall be folded in half, sealed into a bag form in such a manner as to minimize exposure of the interior to airborne particles, and sampled as a bag.

12.1.6.2 RINSING. Through this opening (see 12.1.6.1) 100 ml. of solvent (MSFC-SPEC-237A) for each square foot of interior surface shall be introduced from a wash bottle or similar apparatus. A bag having less than 1 square foot of interior surface shall be considered as 1 square foot. The opening shall then be held shut by a practical means. The exterior of the bag shall then be rinsed down with the same agent to prevent exterior particles from being picked up when the bag is decanted. The cleaning agent within the bag shall be agitated by a gentle but rapid sloshing.

12.1.6.3 COLLECTION OF SAMPLE. The cleaning agent within the bag shall be poured out through the same opening, held shut during rinsing, through a microporous membrane filter.

12.1.6.4 TESTING. The effluent of the rinse test shall be examined for particulate matter by the particle count method in accordance with the requirements of Chapter 13 or SAE-ARP-598. The NVR of the solvent rinse shall be determined in accordance with the requirements of Chapter 13. Individual bags or pieces of material tested for cleanliness shall not be used to package precision cleaned items.

12.1.7 PACKAGING OF PRECISION CLEANED PARTS. This section establishes methods to be employed for packaging of parts/components that have been precision cleaned.

12.1.7.1 ENVIRONMENTAL. All intimate packaging operations shall be accomplished within a clean room or clean work station.

12.1.7.2 HANDLING OF COMPONENTS. Clean, low-lint white nylon or neoprene rubber gloves shall be worn when handling cleaned components during the packaging operations.

12.1.7.3 GARMENTS. Clean room attire as prescribed in Chapter 10 shall be worn during packaging operations.

12.1.7.4 PACKAGING MATERIALS. Materials approved for the inner and outer bags shall conform to the requirements of 12.2. Precision packaging materials surface cleanliness requirements shall be in accordance with either Level I or II of Table I.

12.1.7.5 SIZE. The size of the bag to be used must be determined in relation to the part. Adequate room within the primary barrier (inner bag) shall be allowed in order that the part be easily encapsulated.

12.1.7.6 STRENGTH. The strength of the bag to be used must be determined in relation to the part contained. Many bags used have three sides sealed, as contrasted to end-sealed tubing. When a seal test is to be performed, the method described by MIL-P-116D shall be used.

12.1.7.7 SEALING ORIFICES. Where parts have many orifices, it may be necessary to seal each one. During assembly, they shall not be exposed to the environment more than one at a time in order to retard the entry of particulate contamination. Cut squares of clean film and then tape them in place on noncritical surfaces. Use a polyester (such as Mylar) tape with low adhesive and residue properties. For male fittings and tube ends, wrap the protrusion with film and draw the film over the critical portions of the part or over the film itself by stretching the tape. The tape used shall be a polyvinyl chloride type conforming to PPP-T-66, Type I, Class B. Connector nuts with tubing shall be restrained to prevent free motion. After packaging, use tape over the clean film to tightly secure the nut.

12.1.7.8 WRAPPING. Where small or large parts have sharp edges and projections, the part shall first be wrapped in two to four layers of sheet film or tubing. The layers of film may be secured with polyvinyl chloride tape per 12.1.7.7. After the part is wrapped, it shall be enclosed in the first barrier bag and sealed. To restrict the motion of the part in relation to the bag, the

bag shall be evacuated thoroughly by cutting a corner of the sealed bag and inserting this slit into the opening of a vacuum tool with an orifice of approximately 1/8 x 1/2 inch. After all the air has been evacuated, seal the opening, over-bag, and repeat the evacuation procedure. Alternately, the over-bag shall be flushed with dry nitrogen gas (MSFC-SPEC-234A) that has been passed through a 10 micron absolute filter. Then the over-bag shall be evacuated and sealed.

12.1.7.9 PLASTIC CLOSURES. When plastic closures, e.g., caps, plugs, and heat shrinkable sleeves are specified to seal openings of items with precision-cleaned internal surfaces, the closures shall be of suitable size and type and shall not be detrimental to the item.

12.1.7.10 METALLIC CLOSURES. When closure plates are specified to close flanged items, the materials used shall be precut and drilled aluminum alloy or stainless steel 0.125 inch minimum thickness.

12.1.7.11 DISSIMILAR METALS. To prevent galvanic corrosion, metals dissimilar to item flanges shall not come in contact with the flange. Refer to MSC-Standard 63. See Chapter 3.

12.1.7.12 LOX AND GOX COMPATIBILITY. LOX and GOX parts, components, subsystems, and systems shall be protected in an inner bag of 2 mil fluorohalocarbon film such as Aclar 33C meeting MSFC-SPEC-456.

NOTE: LOX compatible bags must be sealed on <u>all</u> sides, never centerfolded.

12.1.7.13 PURGING GASES. When purging is specified, the material shall be precleaned, dry, inert gas, such as argon conforming to MIL-A-18455 or nitrogen conforming to MSFC-SPEC-234A Type I or equivalent. Gases shall be prefiltered to meet the cleanliness level of the item being precision packaged.

12.1.7.14 PRESSURE-SENSITIVE TAPE. When tape is specified, the material shall be pressure sensitive, vinyl, and shall conform to PPP-T-66, Type I, class B, unless otherwise specified.

12.1.7.15 PRESERVATIVES. Preservative materials shall not be used on items which have been precision cleaned.

12.1.7.16 CERTIFICATION. A certification of cleanliness level decal shall be placed between the outer and inner bag. Decals specified in section 12.8 of this chapter may be utilized for this purpose. Special information, such as long term storage provisions and/or special provisions for preservation, may be included within the outer clean bag.

12.2 TYPE I CLOSURE GENERAL REQUIREMENTS. Type I closure requirements are as specified herein.

12.2.1 FILM CUSHIONING. Heavy items or items having threads, sharp points, edges, etc., which may puncture or otherwise damage the barrier bags, shall be overwrapped with a sufficient amount of 2 mil Nylon 6 film to form a cushion. Small, light items which, if dropped, would not cut or otherwise damage the barrier bags need not be film cushioned. The cushioning film shall be secured with an approved tape (PPP-T-66, Type I, class B) whose adhesive shall not come in contact with the body of the precision-cleaned item.

12.2.2 INNER BAG. Each cushioned item shall be placed into a barrier bag of Nylon 6, 2 mil material.

12.2.3 PURGING. Interior of the barrier bag and cushioned item contained therein shall be purged with an inert gas as specified in 12.1.7.13 immediately prior to evacuation and heat sealing.

12.2.3.1 PURGING PROCESS. Purging shall be accomplished by directing a stream of inert gas into the bag and over the contents for a sufficient length of time to replace the entrapped air with inert gas. During this process, the bag shall be heat sealed in close proximity to the item. A vacuum shall be pulled on the bag prior to sealing.

12.2.3.2 SEALING TECHNIQUES. Bag sealing techniques shall assure that the volume of gas sealed in the bag is the minimum possible, thus permitting room for expansion of entrapped gas during air shipment.

12.2.4 CERTIFICATION DECAL. The bagged item shall be identified with a decal containing identification, inspection, and certification of cleanliness information. Decals described in section 12.8 of this chapter shall be used for this purpose. Decals shall be applied to the seal on the inner bag in such a manner as to detect opening or tampering with the inner bag.

12.3 DETAIL REQUIREMENTS - EXTERNALLY CLEANED ITEMS. Externally cleaned items, e.g., valve seats, seals, springs, filter elements, etc., shall be cushioned, bagged, purged, identified, heat sealed, and marked in accordance with provisions of general requirements for Type I closures.

12.3.1 SANDWICH PACKAGE. An acceptable alternative for light, regular, or symmetrical items, e.g., "O" rings, seals, gaskets, etc., is a sandwich package consisting of heat sealing a number of identical items between two Nylon 6 transparent film sheets of 2 mil material, providing each item is in a separate purged and heat-sealed compartment and each compartment may be separated from the others by cutting with scissors without spoiling the integrity of the remaining compartments. The sandwich package shall then be identified with evidence of cleaning according to 12.2.4 and placed into a 6 mil bag of tinted antistatic polyethylene film which shall then be purged and heat sealed according to 12.2.3.

12.3.2 INTERNALLY CLEANED ITEMS - SEALING OF OPENINGS. Internally cleaned items, e.g., valves, tanks, regulators, etc., shall be purged and all fittings or other openings leading to cleaned inner surfaces shall be capped, plugged, or otherwise sealed with clean closures in accordance with 12.1.7.9.

12.3.3 DISPOSITION OF SEALED ITEMS. Sealed internally cleaned items shall be individually cushioned, bagged, purged, and heat sealed, identified, and marked in accordance with provisions of general requirements for Type I closures.

12.4 TYPE II CLOSURES - LARGE, HEAVY, OR ODD SHAPED ITEMS. Items which cannot normally be heat sealed in a transparent film bag because of size, weight, or configuration and have precision-cleaned interior surfaces only shall be prepackaged as follows.

12.4.1 CAPPED OR PLUGGED CLOSURES. All fittings or other openings leading to precision-cleaned inner surfaces shall be capped, plugged, or otherwise sealed with plastic closures in accordance with 12.1.7.9. Plastic closures shall mate with and be tightened to sealing surfaces to preclude breathing of the sealed item.

12.4.2 FILM SHEET CLOSURES. Items containing openings leading to precision-cleaned inner surfaces which cannot be sealed with plastic caps or plugs shall have each opening overlayed with two sheets or bags of 2 mil Nylon 6. Each sheet or bag shall be secured in place by at least two tight wraps of tape per 12.1.7.14. The tape shall not contact the body of the item.

12.4.3 CERTIFICATION DECAL. Decals described by section 12.8 of this chapter shall be secured to the sealing film or closure to indicate compromise of the seal if broken.

12.4.4 FILM OVERWRAP. Each item with sealed openings shall be completely overwrapped with 6 mil tinted antistatic polyethylene film. The overwrap shall be secured with tape per 12.1.7.14, or heat sealed where practicable. In any case, sealing of items that may be exposed to temperature variations during transport and storage shall be adequate to prevent the internal volumes of the item from breathing.

12.4.5 FLOATING BARRIER BAG. Completely closed, sealed, and identified items shall be enclosed in a floating bag in accordance with Method IIa of MIL-P-116D and as supplemented by Air Force Manual AFM 71-1 except that the gaskets and barrier bag materials shall be 6 mil tinted antistatic polyethylene film.

12.5 TYPE III CLOSURES - HOSE AND TUBE ASSEMBLIES. Cleaned hose and tube assemblies, where external surfaces do not require critical or visual cleanliness, shall be purged internally and sealed to preserve their cleanliness. Each fitting shall be sealed with the appropriate plastic closure.

12.5.1 FILM SLEEVE. Each purged, sealed, and identified hose or tube assembly shall be placed into a 6 mil film sleeve of tinted antistatic polyethylene film, purged, heat sealed, and marked in accordance with provisions of general requirements for Type I closures when external surface cleanliness is required.

12.5.1.1 FLANGED ITEMS. Flanged items with cleaned internal surfaces only shall be closed as follows.

NOTE: Place a minimum of two layers of precut Nylon 6 film gaskets, each 2 mil thick, over the flange face. Apply metallic closures plate over film gaskets; insert attachment hardware through all flange holes and tighten to recommended torque value for type and size attachment bolt used. Each completed flange closure sealed with film in accordance with this paragraph shall be sealed with a decal as described by 12.2.4.

12.6 TYPE IV CLOSURES - ELECTRICAL AND ELECTRONIC ITEMS. Electrical and electronic items which will require testing upon arrival at destination and during storage shall be prepackaged in a manner which will permit access to the leads, pigtails, etc., without spoiling the integrity of the unit package. Each package shall be sealed with a certification decal as described by 12.2.4.

12.7 DISPOSITION OF PREPACKAGED ITEMS. Completed precision clean prepackaged items shall be removed from the clean room and shall be placed in an appropriate container or storage area to protect the plastic bags and contents.

12.7.1 UNIT PACKAGING. Prepackaged precision-cleaned items which have been processed in accordance with this chapter shall be unit packaged in accordance with Level A of MIL-P-007936, MIL-E-17555, and as supplemented by MIL-P-116D.

12.7.2 PACKING. Packing shall be in accordance with Level A or B, as applicable, of MIL-P-007936 and MIL-E-17555.

12.8 DECALS. Decals procured for or utilized to meet the requirements of this section are not intended for direct application to parts or equipment as the decals are not required to be compatible with fuels or oxidizers. These pressure sensitive decals shall be used as a sealing method on the packaging of precision-cleaned items in such a manner that cleanliness integrity violation may be readily detected. These are always applied to the outside of the inner bag.

12.8.1 DECAL MATERIAL. Decals shall be of a thin material that fractures with any attempt at removal.

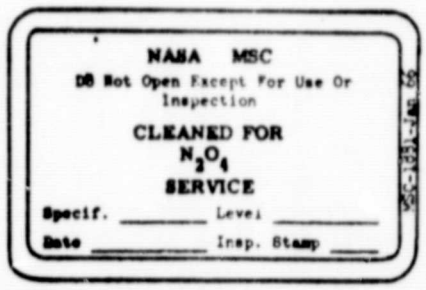
12.8.2 DECAL APPLICATION. Decals shall be applied on heat-sealed edges of packaging material and over the ends of taped seals.

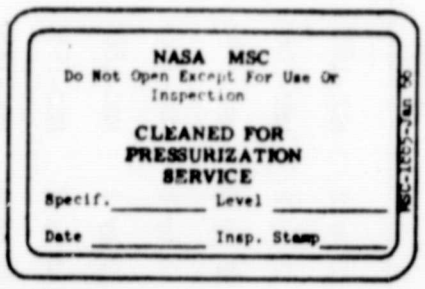
12.8.3 DECAL TYPES. Decals utilized at MSC shall be as shown by 12.8.4 and 12.8.5. Contractors and subcontractors at off-site locations may utilize any decal type that will fracture when removal is attempted. When alternate decals are used at off-site locations the decal nomenclature shall reflect the information required on the decals shown by 12.8.5 plus any additional information that may be required.

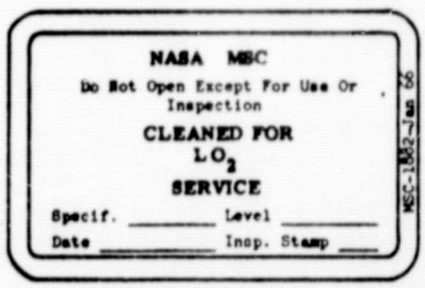
12.8.4 DECAL DESCRIPTION

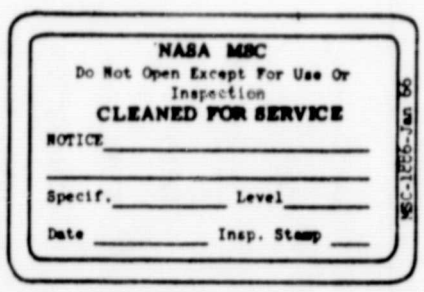
SERVICE	BACKGROUND COLOR	FED-STD-595 NUMBER	TRIM COLOR	FED-STD-595 NUMBER	SIZE, IN.	FORM NUMBER
Nitrogen tetroxide, N_2O_4	White	37875	Green	14187	1 1/2 by 2	MSC-1881
Liquid oxygen, LO_2	White	37875	Green	14187	1 1/2 by 2	MSC-1882
Aerozine-50, UDMH	White	37875	Red	11105	1 1/2 by 2	MSC-1883
Liquid hydrogen, LH_2	White	37875	Red	11105	1 1/2 by 2	MSC-1884
Pressurization	White	37875	Orange	32246	1 1/2 by 2	MSC-1885
Cleaned for service	White	37875	Red/white	11105/37875	1 1/2 by 2	MSC-1886
Certified	White	37875	Green	14187	1 1/2 by 2	MSC-1887
Certified for special use	White	37875	Yellow/white	13655/37875	1 1/2 by 2	MSC-1888
Liquid nitrogen, LN_2	White	37875	Green	14187	1 1/2 by 2	MSC-21

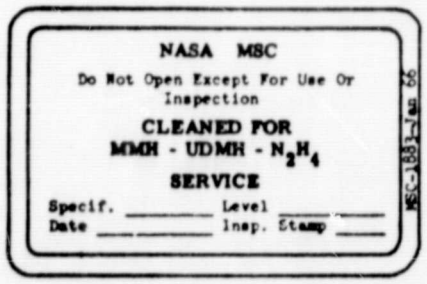
12.8.5 EXAMPLE OF DECALS

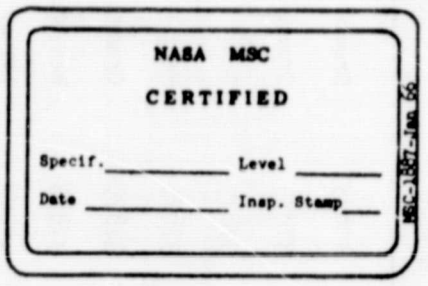


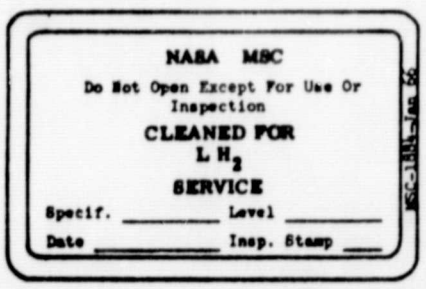


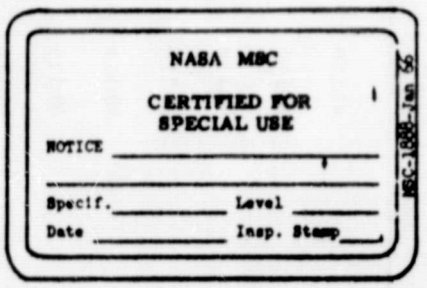


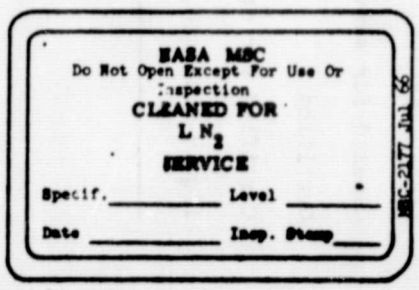












CHAPTER 13
FLUID ANALYSIS

13.0 FLUID ANALYSIS

This chapter establishes approved analytical procedures for fluids used on spacecraft programs. Procurement specifications for fluids generally provide detailed analytical procedures which shall be utilized whenever possible.

13.1 RESPONSIBILITY FOR INSPECTION. The supplier of a fluid is responsible for all quality assurance tests in accordance with the requirements specified in the procurement document. Inspection records of the examination and tests shall be kept complete and available to the procuring organization. Such records and certification as provided shall be utilized by the user to the maximum extent possible in performing subsequent tests.

13.2 ANALYTICAL PROCEDURES. The analytical procedures listed herein shall be utilized when procurement documents do not list a specific procedure or when a referee procedure is required.

13.2.1 SPECIFIC GRAVITY. Specific gravity at 25/25°C. (77/77°F.) of a given fluid shall be determined by the pycnometer method according to the following specifications.

13.2.1.1 INDUSTRIAL WATER. In accordance with ASTM D1429-60.

13.2.1.2 HALOGENATED SOLVENTS. In accordance with ASTM D2111-62T, Method C.

13.2.1.3 AROMATIC HYDROCARBONS. In accordance with ASTM D891-59, Method C.

13.2.2 DISTILLATION RANGE. Determination of the distillation range of the material shall be in accordance with Method 1001 of Federal Test Method Standard 791. Make corrections for the barometric pressure and thermometer emergent stem, taking the temperature readings for compliance with the distillation requirements.

13.2.3 ACIDITY. The pH of a sample specimen shall be determined in accordance with ASTM D1293-62T.

13.2.4 WATER CONTENT. Water or moisture content shall be determined in accordance with respective provisions of the appropriate procurement specifications.

13.2.5 ODOR. Odor determination shall be conducted in accordance with ASTM D1292-63. Where an odor determination is required of a total gaseous system, a 10cc. gaseous sample shall be extracted for each test.

13.2.6 SUSPENDED MATTER. Suspended matter shall be determined by inverting a bottle of the sample specimen and examining by transmitted light. Inspection shall be visually conducted by a person with normal or corrected 20/20 vision.

13.2.7 NVR (NONVOLATILE RESIDUE). NVR shall be determined in accordance with ASTM D2109-64.

13.2.8 ELECTRICAL CONDUCTIVITY. Electrical conductance shall be determined according to ASTM D1125-64.

13.2.9 STERILITY. Sterility determination shall be conducted in accordance with requirements contained in MSC-SPEC-SD-W-0020.

13.2.10 SURFACE TENSION. Surface tension shall be determined according to ASTM D1590-60.

13.2.11 HALIDES. ASTM D512-67, Method C, should be followed to quantitatively determine the presence of halide ions (chloride, bromide, and iodide, but not fluoride). This method may be applied to a water sample containing primarily chloride concentration, thus giving a linear relationship for chloride absorbance/concentration over the range of 0.02 to 10.0 ppm. A photometric calibration graph must be constructed to verify linearity over the halide concentration range considered.

If a specific test is required, then the following specifications must be followed for halide identification.

13.2.11.1 FLUORIDE. Fluoride analysis shall be performed in accordance with ASTM D1179-61.

13.2.11.2 CHLORIDE. Chloride analysis shall be performed in accordance with ASTM D512-67. Method A.

13.2.11.3 BROMIDE. Bromide analysis shall be performed in accordance with ASTM D1246-55.

13.2.11.4 IODIDE. Iodide analysis shall be performed in accordance with ASTM D1246-55.

13.2.12 ASSAY AND CHEMICAL IMPURITIES IN:

13.2.12.1 HELIUM. The apparatus described in MSFC-SPEC-364B shall be employed to establish purity.

13.2.12.2 HYDROGEN. The purity shall be determined by a suitable gas chromatographic technique; see MSFC-SPEC-356.

13.2.12.3 NITROGEN. The apparatus as described in MSFC-SPEC-234A shall be employed to establish purity.

13.2.12.4 OXYGEN. The purity shall be determined by mass spectroscopy and/or gas chromatography as specified in MSFC-SPEC-399A or MIL-O-27210D.

13.2.12.5 METHYL ALCOHOL. The apparatus and procedures as described in O-M-232D shall be employed to establish purity.

13.2.12.6 ETHANOL. The apparatus and procedures as described in O-E-670B shall be employed to establish purity.

13.2.12.7 ISOPROPYL ALCOHOL. The apparatus and procedures as described in TT-I-735A shall be employed to establish purity.

13.2.12.8 NITROGEN TETROXIDE. The apparatus and procedures as described in MSC-PPD-2B shall be employed to establish purity.

13.2.12.9 HYDRAZINE-UNS-DIMETHYL HYDRAZINE. The apparatus and procedures as described in MIL-P-27402 shall be employed to establish purity.

13.2.12.10 MONOMETHYL HYDRAZINE. The apparatus and procedures as described in MIL-P-27404 shall be employed to establish purity.

13.2.12.11 PRECISION CLEANING AGENT. The apparatus and procedures as described in MSFC-SPEC-237A shall be employed to establish purity.

13.2.12.12 TRICHLOROMONOFLUOROMETHANE SOLVENT. The apparatus and procedures as described in MSC-PPD-1 shall be employed to establish purity.

13.2.13 SILTING. A 40-power maximum microscope shall be used to observe silting, using a 100 ml. sample of liquid.

13.2.14 PARTICULATE

13.2.14.1 TOTAL WEIGHT (LIQUIDS). Total weight of particulate shall be determined using the method listed in section 4.5.6 of MSC-PPD-2B (Propellant, Inhibited Nitrogen Tetroxide) except that for materials other than nitrogen tetroxide, a 0.45 micron, 47 mm. diameter, cellulose ester membrane should be substituted for the Teflon membrane. Also, no cooling of the filter flask is necessary except for nitrogen tetroxide.

13.2.14.2 SIZING AND COUNTING PARTICULATE CONTAMINATION. Particulate determination shall be in accordance with the requirements of SAE-ARP-598. A teflon membrane filter shall be used for particulate determination when liquid oxygen is the fluid being sampled.

13.2.15 HYDROCARBON DETERMINATION. Test methods and specifications for the determination of hydrocarbon impurities in gases may use different gases as the common reference. For example, unknown hydrocarbons may be referenced as the equivalent in methane (CH_4), ethane (C_2H_6), propane (C_3H_8), etc. This section lists the common reference gases and provides conversion factors for equilibrating the various references. This section applies to hydrocarbon determinations obtained by utilizing a hydrocarbon counter such as the Beckman Hydrocarbon Analyzer 109A. This section should not normally be utilized for gas chromatography.

13.2.15.1 HYDROCARBON EQUIVALENTS. Hydrocarbon equivalents of unknown gas mixtures, when expressed as a standard gas, are inversely proportional to the molecular weight of the gas standard. For example, using methane (molecular weight 16.04) as 1.000, the equivalent in ethane (molecular weight 30.07) would be 0.533, in parts per million by volume. The inherent inaccuracy of the analytical techniques used to determine trace amounts of hydrocarbons does not warrant the use of equivalents expressed to three decimal places. A relationship based on the number of carbon atoms in the standard gas is normally sufficiently accurate to provide meaningful conversion from one standard gas to the other. An equivalency table and the calculation of equivalents is shown below.

Hydrocarbon Equivalents[1]

Using Various Gas Standards

Gas	Conversion Equivalents
Methane (CH_4)	1
Ethane (C_2H_6)	2
Propane (C_3H_8)	3
Butane (C_4H_{10})	4
Pentane (C_5H_{12})	5

NOTE 1: These factors are contingent on similar test conditions such as equal volume sample concentrations and equal flow rates through the test apparatus.

CALCULATION OF EQUIVALENTS

The concentration of one standard gas in terms of another may be expressed by the following formula.

$$C_A \ Conc_A = C_B \ Conc_B$$

C_A = Conversion equivalent of gas A

$Conc_A$ = Concentration (in ppm by volume) of gas A

C_B = Conversion equivalent of gas B

$Conc_B$ = Concentration (in ppm by volume) of gas B

SAMPLE DETERMINATION

Given a concentration of 10 ppm. by volume of propane, what is the equivalent concentration of pentane?

C_A = 3 for propane

$Conc_A$ = 10 ppm by volume for propane

C_B = 5 for pentane

X = Concentration of pentane

$C_A \ Conc_A = C_B \ Conc_B$

3 x 10 ppm/vol = 5X

$\frac{30}{5}$ = 6 ppm/vol = X

CHAPTER 14
CONTAMINATION CONTROL DURING REPAIR, REPLACEMENT, AND MAINTENANCE

14.0 CONTAMINATION CONTROL DURING REPAIR, REPLACEMENT, AND MAINTENANCE

This chapter establishes the minimum contamination control requirements for repair, replacement, or maintenance operations performed on an installed spacecraft fluid system and associated GSE (ground support equipment) which has previously been precision cleaned. The cleanliness of precision-cleaned, contaminant-critical systems can be compromised by improper contamination control techniques during any operation in which the system is opened to an uncontrolled environment. Localized clean operations may be conducted in a number of ways, any of which are acceptable provided these general requirements are met.

14.1 OPERATIONS PRECEDING SYSTEM ENTRY

14.1.1 AREA CLEANUP. The area in which the repair, replacement, or maintenance is to be performed shall be made visibly clean. Prior to this cleaning, all loose or extraneous equipment shall be removed from the area.

14.1.2 CONTROLLED ENVIRONMENT ENCLOSURE. A temporary enclosure shall be constructed around the portion of the system to be opened so as to preclude contaminating the open system (or replacement part) by exposure to the normal working environment. Depending on the size of the components or the complexity of the repair operation, the enclosure may be a small, "dry-box" design or a large, walk-in, tent-type configuration.

The air source selected shall be capable of furnishing filtered air to provide an environment equivalent to or better than the environment required for the initial assembly of that particular system.

14.1.2.1 SMALL "DRY-BOX" ENCLOSURES. This enclosure, normally made of a polyethylene sheet, shall be large enough to admit the hands. The inside of the enclosure shall be wiped visibly clean and then the system opened to admit a flow of dry filtered inert gas from the system. The gas flow pressure is such that no dust or other environmental contaminants can enter the enclosure.

14.1.2.2 WALK-IN TENT ENCLOSURES. The nature of the operation may require the construction of a large, walk-in enclosure. This enclosure shall be made of a polyethylene sheet, suitably reinforced (if necessary) and shall be wiped visibly clean prior to use. Air shall be pumped into the enclosure so as to provide a controlled environment required for the system components. This shall be accomplished by properly operating a HEPA filter assembly and temperature and humidity controls as required. Airflow to the enclosure shall be at such a rate as to preclude dust or other environmental contaminants from entering the enclosure; however; the influent airflow shall not be so great as to force contaminants into the opened system.

14.1.3 SYSTEM PURGE. A purge using an inert gas shall be established in the system prior to opening the system. The gas shall meet or exceed system cleanliness level requirements. The gas flow rate shall be such that a positive pressure from the system to the environment shall prevail upon opening the system. The purge shall continue until the repair, replacement, or maintenance operation is completed and the system is closed. When a gas purge cannot be applied, the open system lines shall be protected by an approved plastic bag securely tied around the open port or sealed by an approved method to prevent the entry of contaminants.

14.2 REPAIR, REPLACEMENT, OR MAINTENANCE OPERATIONS

14.2.1 CLOTHES. Personnel in the enclosure during repair, replacement, or maintenance operations shall wear clean room attire as required to maintain the cleanliness requirements of the system components. Chapter 10 describes clean room garment requirements.

14.2.3 ENCLOSURE OPERATIONS. No operations shall be conducted in the enclosure unless the system purge and filtered air inputs are on. "Operations" shall include the presence of properly clothed personnel, unwrapping of precision-packaged components or tools, opening or closing the system, installing or removing components, etc.

14.3 REMOVED PARTS. All contamination-sensitive parts removed or replaced shall have the following performed inside the localized clean area.

14.3.1 Components, parts, or systems removed shall have critical surfaces or tube openings closed with clean protective plugs or caps or covered with a clean plastic bag. Connectors shall have clean covers installed or covered with a clean plastic bag.

14.3.2 The item shall be completely covered with a plastic bag for transport to the clean room.

14.3.3 All subsequent operations involving parts, systems, etc., which are to be reinstalled on the spacecraft shall be conducted in a clean room of a level meeting the cleanliness requirements established for the specific item.

14.3.4 Upon completion of final cleaning and prior to leaving the clean room, all ports, connectors, or other openings shall be protected as specified in 14.3.1 and the item shall be packaged in precleaned plastic or other compatible material.

14.3.5 All protective coverings shall be removed inside the localized clean areas.

14.4 EXPOSED CONTAMINANT-SENSITIVE SURFACES. All surfaces, lines, ports, etc., opened or exposed due to part removal or system break-in shall be protected with caps, covers, or plugs, to prevent contamination of the exposed system. In addition, a clean plastic bag shall be placed over the plugged or capped area.

14.5 CLEANING AND SAMPLING. Repair, replacement, or maintenance operations which result in the contamination of interfacing items shall require cleaning and sampling of the contaminated items to assure the cleanliness integrity of the assembly being serviced.

14.5.1 PRECISION CLEANING. When precision cleaning operations are required during repair, maintenance, or replacement operations such cleaning shall be in accordance with the requirements of Chapter 11.

14.5.2 FLUID SAMPLING. Sampling operations, when required, shall be in accordance with the requirements of Chapter 21.

CHAPTER 15
WELDING/BRAZING CONTAMINATION CONTROL

15.0 CONTAMINATION CONTROL DURING WELDING ON BRAZING OPERATIONS

This chapter establishes the minimum work station and proce · cleanliness requirements for welding or brazing operations on spacecraft and supporting equipment at manufacturing facilities and field sites.

15.1 PRECLEANING REQUIREMENTS. Immediately prior to brazing or welding, the applicable critical surface areas of the metals to be joined shall be freed of oil, grease, water, solvents, paints, ink, shop dirt, rust, scale, weld slag, brazing flux, metal chips, decals, preservatives, and all other foreign matter. A common aerospace cleaning procedure which meets the general cleaning requirements of Chapter 11 shall be utilized for this purpose.

15.1.1 MATERIAL COMPATIBILITY. Fluids or solutions used to clean materials for welding or brazing shall be certified as being compatible with the materials being cleaned.

15.1.2 HANDLING OF PARTS. All precleaned critical surface areas to be brazed or welded shall not be handled except with clean gloves conforming to the requirements of Chapter 10. Care shall be taken not to recontaminate these surfaces, and the gloves shall be worn during the brazing or welding operations. The workbench or other fixtures upon which the parts to be joined may be placed shall be visibly clean. Tools or equipment used to align the surfaces to be brazed or welded shall be cleaned of all foreign materials prior to using them in the process of locating the assembly or part to be brazed or welded.

15.1.3 INSPECTION METHODS. The inspection methods described herein shall be used to verify item cleanliness.

15.1.3.1 ULTRAVIOLET LIGHT (BLACK LIGHT). Precleaned areas to be joined shall be inspected with an ultraviolet light source of 3200 to 3800 Angstroms. Any evidence of fluorescent materials shall be cause for recleaning. Ultraviolet light inspection will not detect

common hydrocarbon fuels, some silicone greases, MIL-O-5606 hydraulic oil, thread sealants, and fluorocarbon greases commonly found as contaminants on metal surfaces. Ultraviolet light will cause the following commonly used materials to fluorescese; most water soluble machining and cutting oils, some lints, molybdenum disulfide, MIL-O-6086 lubricating oil, MIL-G-4343 grease (DC-55), silicates from cleaning solutions, and some inorganic compounds that are found in fluorescent penetrant inspection fluids.

15.1.3.2 VISUAL OBSERVATION. Direct visual observation shall be made of all accessible surfaces prior to brazing or welding to detect the presence of substances such as oils, greases, preservatives, corrosion products, weld slag and scale, shop or other foreign materials. Clean borescopes or other similar devices shall be used for the detection of such substances on the surface of inaccessible areas. The presence of corrosion products, metal chips, casting, molding and/or forging scale, weld scale, oil, grease, paints, preservatives, decals, and other contamination or foreign matter detrimental to brazing or welding operations shall be cause for recleaning until the surfaces are visibly clean.

15.1.4 CONTROL OF BRAZE ALLOY CONTAMINATION. Braze alloy contamination will adversely affect valve seats or orifices with a resulting impairment of component operation. Braze alloy contamination shall be controlled by (1) controlling the flow rate of the argon purging gas, (2) using a hygrometer for continuous dewpoint checks of the purging gas as a low dewpoint is preferred, (3) drying the argon gas with silica gel, and (4) using high purity braze alloys. If possible, use a clean stainless steel or aluminum cover over the operating area.

15.1.5 PURGING OF FLUID SYSTEMS. Immediately prior to brazing or welding a component to a fluid system, the remaining system shall be purged both upstream and downstream of the component. Where purging media cannot be made to flow due to blockage by check valves or dead-ended lines, a vacuum shall be applied to effect the same result (providing that vacuum does not damage the system). The purge gas (argon) shall be dry, oil free, and shall

have been filtered through a 10 micron absolute filter and processed through a dehydrator so that its dewpoint is minus 63.5 degrees F. at one atmosphere or a maximum of 41 ppm. by volume moisture content at 70 degrees F. An envelope of protective inert atmosphere shall be provided around a brazing operation using a flow of argon conforming to MIL-A-18455 supplied within a suitable working enclosure (such as "plastic tent"). The same inert gas is piped into the interior of tubing to be joined by brazing in order to provide complete protection from oxidization in the areas being brazed. A drying column, when used, shall be checked each day before the argon is used for brazing or welding operations to ensure that the desiccant is effective. The moisture content shall be checked after each installation of a full gas cylinder. Desiccant effectiveness shall be checked by an electrolytic cell type hygrometer. Clean metal tubing shall be used for purge lines to minimize moisture pickup from nonmetallic purge lines.

15.1.6 FIELD OPERATIONS. All brazing and welding operations to be performed in the field shall be preplanned to ensure that contamination by the outside elements shall not impair the integrity of the joint. The number of field connections shall be kept to a minimum by brazing and welding assemblies rather than components. To promote freedom from system contamination all field joining shall be accomplished with a positive purge pressure of dry, 10 micron filtered nitrogen gas conforming to MSFC-SPEC-234A, or 10 micron filtered argon gas conforming to MIL-A-18455. Only argon gas may be used for purging stainless steels.

Flow shall be produced at the junction point out of both the system and assembly to be joined. The assembly to be brazed or welded shall not be brought into the field until all preinstallation operations such as alignment, removal of blind flanges, insertion of bolts, etc., have been accomplished. The assembly to be brazed or welded shall not be exposed until brazing or welding operations start. The nitrogen or argon purge shall be discontinued only while welding or brazing. Special attention shall be given to insure complete evacuation of nitrogen or argon atmosphere prior to start of welding. After completion of the welds, positive pressure of 10 psig nitrogen or argon gas shall be reinstated.

15.1.7 BRAZING TUBING. Contamination may occur when tubing is inserted into a joint prior to brazing. The edge of the tube may scrape off small particles from the inside edge of the braze alloy ring. This situation shall be alleviated by making a generous chamfer on the tube and by recessing the braze alloy ring in the joint. If the connection is separated for repair by "plucking," i.e., removing the joint by heating above the brazing alloy melting point and then slipping the parts off the tube, care shall be taken to prevent particles of the brazing alloy from entering the inside of the tubing.

15.1.8 CONTROL OF BLOWN-HOLE CONTAMINATION. Contamination resulting from holes blown in tubing can occur during the initial automatic welding process. In order to eliminate the causes of blown holes in stainless steel lines, corrective action shall be taken in regard to (1) preheating to assure positive drying, (2) defective and/or worn tooling, (3) improper fitup, and (4) electrode contact with or breaking off into the molten bead.

15.1.9 POST-BRAZE CLEANING. Brazed assemblies shall be cleaned by suitable means to remove fluxes which can accelerate corrosion. Prior to flux removal, the part shall have been allowed to cool in air to room temperature. Following post-braze cleaning, the parts shall be precision cleaned in accordance with Chapter 11.

15.1.10 PRECAUTIONS IN REMOVING BRAZED OR WELDED COMPONENTS. Specialized cutting tools shall be employed for the removal of components. Hacksaws or similar tools capable of generating particulate contamination shall not be employed at any time. The number of times a brazed joint shall be heated shall be limited to prevent contamination of the base metal with the braze alloy. Immediately after removal of a component by debrazing, it shall be deplucked and the ends shall be prepared for rebrazing. The open system shall be purged both upstream and downstream of the removed component and open lines shall be capped immediately after this purge until just prior to rebraze. Where the purging gas cannot be made to flow due to blockage by check valves or dead-ended lines, a vacuum shall be applied to effect the same results (providing that vacuum does not damage the system).

CHAPTER 16
SPACECRAFT CLEANLINESS

16.0 SPACECRAFT CLEANLINESS

This chapter is based on the premise that cleanliness obtained through a combination of good housekeeping and personnel controls is adequate for all operations involving the exterior of a spacecraft. Provisions are made for localized cleanliness control when critical parts or systems are removed, replaced, or serviced. A similar position is taken on the spacecraft interior in that no visible dirt, soil, or hydrocarbons are evident prior to the start of testing, preflight, or final checkout. These precautions, coupled with the requirements for a controlled environment for the interior of the vehicle are considered adequate to insure a practicable level of cleanliness.

16.1 REQUIREMENTS. This chapter establishes the minimum cleanliness requirements for assembled spacecraft in manufacturers' final assembly and checkout area, environmental test chambers, and at launch site test and checkout areas. It also includes requirements for maintaining cleanliness standards during shipment and while components are being removed or replaced. Cleanliness levels of subsystems shall be as established in the applicable subsystem specification.

16.1.1 TEST AND CHECKOUT. General operations at manufacturers' final assembly and checkout area, and KSC checkout areas which involve the spacecraft, shall be conducted under environmental conditions specified for a controlled work area as shown in Chapter 8. In addition, the requirements of 16.1.2 through 16.3.6 shall be met.

16.1.2 PERSONNEL ACCESS. Access to the immediate vicinity of the test stand or work fixture shall be restricted to those personnel essential to the operation. Details of control shall be jointly established by the responsible test organization and the operating organization, contractor, or the cognizant MSC representative.

16.1.3 GARMENTS. Clean room garments, as specified in Chapter 10, shall be worn by personnel working in, or visiting, the controlled work area.

16.1.4 ACCESS TO SPACECRAFT. Entry to the crew bay shall be restricted to personnel who must enter to perform necessary tests, checkout, maintenance, or repair functions. Personnel entering shall wear clean coveralls, foot covers or approved shoe socks, and hoods. Foot covers shall be donned at the entrance to the spacecraft.

16.1.5 SYSTEMS/SUBSYSTEMS ASSEMBLY OR REWORK. Maintenance or parts replacement shall be performed under localized clean operational conditions (as outlined in Chapter 14) when the specifications for the part indicate more rigid contamination control is required than is provided by the surrounding area.

16.1.6 REMOVED PARTS. Packaging shall be provided for all contamination-sensitive parts removed.

16.1.7 CLEANED PARTS. All parts prior to reinstallation on the spacecraft shall be cleaned and precision packaged in a room under conditions which at least meet the manufacturer's cleanliness level as defined in his component specification.

16.1.8 CHECKLIST. An accountability checklist shall be provided for all items taken into the crew bay. There shall be no exceptions. Installed hardware shall be verified by the cognizant quality group and removed parts accounted for. Any item not accounted for shall be located or mutually dispositioned prior to continuation of testing and/or maintenance.

16.1.9 TRAINING REQUIREMENTS. All personnel having access to the spacecraft work area shall be properly trained prior to entry. This training shall be in enough depth to enable these persons to fully implement the intent and requirements of this specification.

16.1.10 CREW BAY CLEANLINESS. The crew bay shall be cleaned at the end of each 24 hour working period by vacuuming and/or wipe down. Vacuum source shall be located outside the work area with only a well-cleaned hose and pickup attachment inside. If this is impractical, an approved industrial type vacuum cleaner with filtered exhaust shall be used.

16.1.11 SPACECRAFT EXTERIOR CLEANLINESS. Vacuuming and wipe down of the outside of the spacecraft shall be performed, as required, to maintain the exterior visibly clean. Wipe down will not be performed if damage to protective coating may result.

16.1.12 SPACECRAFT COVER. The spacecraft shall be covered with a clean, static free, dry, nonabrading cover during any period of 8 or more hours when test or maintenance is not being performed.

16.1.13 CREW BAY ENVIRONMENTAL CONTROL. During normal work activity and/or while hatches are open, the crew bay compartment shall be provided with conditioned, filtered air. Input air to the compartment shall meet the following requirements.

16.1.13.1 Hydrocarbons: Not to exceed 45 ppm (pentane equivalent).

16.1.13.2 Temperature: $70^{\circ} \pm 5^{\circ}F$.

16.1.13.3 Relative Humidity: Not to exceed 50 percent (or less, if necessary, to preclude condensate on cabin interior).

16.1.13.4 Airborne particulate level: Class 100,000 (in accordance with Chapter 6 or FED-STD-209A).

16.1.13.5 Monitoring of crew compartment environmental conditions is not required; however, a regularly scheduled filter replacement and a daily monitoring of input conditions shall be implemented to insure that above requirements are met or exceeded.

16.1.14 ENVIRONMENTAL. The spacecraft and its equipment shall, at all times, be protected from environments which could cause harm, such as salt, moisture, temperature, etc. Suitable recordings shall be made for verification.

16.2 ENVIRONMENTAL TEST CHAMBER OPERATIONS

16.2.1 PREPARATIONS. Prior to installation of the spacecraft, the chamber shall meet the following requirements.

16.2.1.1 CHAMBER INTERIOR. The interior of the chamber shall be visibly clean. Where possible, floors and walls shall be thoroughly vacuumed and walls wiped down or washed to remove any visible soil.

16.2.1.2 CHAMBER SURFACES. All accessible chamber surfaces shall be visually examined and all evidence of grease, oil, or other contaminants removed.

16.2.2 INSTALLATION OF SPACECRAFT. Prior to installation, the exterior of the spacecraft shall be completely vacuumed and wiped down, if necessary, to remove all visible soil. Wipe down shall not be accomplished if damage to protective coatings may result.

16.2.2.1 CREW BAY. The compartment shall be examined and all contaminants removed.

16.2.3 POST-INSTALLATION OF SPACECRAFT. After the spacecraft is located in position and all hookups, electrical and mechanical, are completed, the chamber will be thoroughly vacuumed. All visible hydrocarbons shall be removed before operations are continued.

16.2.4 CLEANING REQUIREMENTS. Cleaning shall be performed daily, as specified in 16.2.3, unless test procedures are in progress.

16.2.5 CREW BAY ENVIRONMENTAL CONTROL. This control is specified in 16.1.13.

16.2.6 SYSTEMS/SUBSYSTEMS ASSEMBLY OR REWORK. This control is specified in 16.1.5.

16.2.7 SUPPLEMENTARY REQUIREMENTS. Supplementary requirements are specified by 16.2.7.1 through 16.2.7.4 for MSC and KSC Environmental Test Chamber operations.

16.2.7.1 ACCESS OPENINGS IN SPACECRAFT. During nonoperational periods, the spacecraft shall have all access openings closed. If maintenance is being performed, the affected area shall be isolated with a properly secured plastic film to prevent entry of contaminants.

16.2.7.2 NONOPERATIONAL PERIODS - CHAMBER ENTRY. Chambers shall have doors closed during nonoperational periods. Entry shall be restricted to those personnel having a need to enter to perform necessary functions. Personnel restrictions as specified in 16.1.4 apply to those operations performed in the spacecraft. Personnel entering the chamber shall wear clean coveralls and caps. Foot covers or approved shoe socks shall be worn by all personnel entering the spacecraft.

16.2.7.3 CONTAMINANT-GENERATION. Contaminant-generating operations such as sanding, grinding, chipping, soldering, drilling, etc., shall not be permitted in the chamber unless specifically approved by the operating organization. If approved, these shall be performed with the controls specified by Chapter 8.

16.2.7.4 ENVIRONMENTAL. These requirements are specified in 16.1.14.

16.3 LAUNCH SITE (INCLUDING LAUNCH COMPLEX)

16.3.1 OPERATIONS. Launch operations involving the spacecraft shall, insofar as practicable, meet the general cleanliness requirements as specified for a controlled work area as defined by Chapter 8.

16.3.2 PERSONNEL CONTROLS. Personnel controls, garments, and accountability checklists shall be provided as specified under test and checkout, 16.1.1.

16.3.3 CONTAMINANT-GENERATION. Contaminant-generating operations shall be conducted only under controls as specified by Chapter 8.

16.3.4 CREW BAY ENTRANCE. Personnel entering the compartment shall don foot covers or approved shoe socks prior to entry.

16.3.5 CREW BAY CLEANLINESS. Compartment shall be cleaned daily by vacuuming and/or wiping down.

16.3.6 CREW BAY ENVIRONMENTAL CONTROL. These requirements are specified in 16.1.13.

16.4 SHIPMENT

16.4.1 CLEANLINESS. The spacecraft interior shall be cleaned to a visibly clean condition prior to shipment by vacuuming and/or wiping down. After ports and openings are secured the spacecraft exterior shall be vacuumed and wiped down, as required, to remove all visible contaminants. Wipe down will not be accomplished if damage to protective coatings may result.

16.4.2 CLEANLINESS PROTECTION. The spacecraft shall have all GSE covers installed and ports, windows, and access openings closed. The packaging techniques and shipping covers shall be adequate to prevent entry of contaminants. For on-site transfer a securely fastened cover will suffice.

16.4.3 ENVIRONMENTAL. These requirements are specified in 16.1.14.

16.5 STORAGE. The following shall be accomplished prior to storage. These requirements are in addition to those preservation and packaging requirements established by the manufacturer and approved by the cognizant MSC representative.

16.5.1 CLEANING. The crew bay shall be visibly clean prior to storage as required by 16.4.1. All GSE covers shall be installed and access openings closed. The spacecraft exterior shall be vacuumed and wiped down to remove all visible contaminants. Wipe down will not be performed if damage to protective coatings may result.

16.5.2 PRESERVATION OF CLEANLINESS. The packaging techniques and shipping covers shall be adequate to prevent entry of contaminants during storage.

16.5.3 ENVIRONMENTAL. These requirements are specified in 16.1.14.

CHAPTER 17

CONTAMINATION CONTROL DURING FABRICATION, ASSEMBLY, AND TESTING

17.0 FABRICATION, ASSEMBLY, AND TESTING CONTAMINATION CONTROL

This chapter establishes the contamination controls that should be exercised to prevent the recontamination of precision-cleaned items.

17.1 GENERAL REQUIREMENTS. The general requirements listed herein shall be followed to minimize the possibility of item contamination or recontamination during operations subsequent to initial cleaning.

17.1.1 FABRICATION. The fabrication operations for each component must be completely evaluated and appropriate cleanliness requirements established for each phase of the operation. Controls such as environmental and personnel controls shall be determined by considering such factors as the complexity of the fabrication or item and whether required cleanliness can be satisfactorily accomplished at a later level of assembly.

17.1.1.1 ITEM PROTECTION. Contaminant-sensitive items shall be protected from contamination sources (shop atmospheres, etc.) by covering or temporary packaging when actual operations are not being performed on the item. Such protection shall be afforded subsequent to the initiation of the required contamination control effort.

17.1.2 ASSEMBLY. Assembly of precision-cleaned items shall be accomplished in an appropriate class clean room as defined in FED-STD-209A or as described by Chapter 6.

17.1.2.1 ASSEMBLY TECHNIQUES. The assembly techniques employed shall be designed to prevent the contamination or recontamination of the items being assembled. Typical techniques to be utilized are listed below. Additional techniques or improvement on the listed techniques should be developed as required for the particular assembly operation being performed.

17.1.2.1.1 Precision-cleaned items shall only be handled with forceps, tweezers, or gloved hands during assembly.

17.1.2.1.2 Lines, hoses, and components with B-nut type fittings shall be aligned with the mating part and only the threaded fitting shall be rotated to prevent the generation of particulate and the subsequent contamination of the item. Movement of the mating surfaces must be held to an absolute minimum.

17.1.2.1.3 Packaging materials shall only be opened using a sharp instrument to prevent the generation of packaging material contaminants.

17.1.2.1.4 Purges shall be used in all possible instances to prevent the entry of contaminants into precision-cleaned items.

17.1.2.1.5 Strict personnel controls shall be maintained to minimize contamination in assembly areas.

17.1.2.1.6 Assembly work areas, benches, tools, and aids shall be maintained in a clean condition to prevent the contact transfer of contaminants.

17.1.3 TESTING. The functional testing of precision-cleaned items is governed by test procedures delineating the test methods and acceptance criteria. When specific contamination control requirements are not stipulated by the governing document, the requirements of this section shall be implemented.

17.1.3.1 TEST FACILITY/EQUIPMENT. The test facility and test equipment shall be verified by inspection and/or sampling as required to assure that the precision-cleaned item will not be contaminated by the facility or the test fluid to be used.

17.1.3.2 FLUID LINE CONNECTIONS. Fluid line connections shall be sealed when not in use to assure equipment cleanliness integrity.

17.1.3.3 MECHANICAL CONNECTION. The mechanical connection of cleaned item/test equipment lines, parts, and fittings shall be accomplished with a minimum of slide fitting to reduce the generation of fitting particles.

17.1.3.4 ITEM PROTECTION. Precision-cleaned items shall be protected from airborne contaminants subsequent to cleaning and prior to testing by the use of temporary packaging, covering, or otherwise protecting the item from airborne particulate fallout. Upon completion of functional testing, the cleaned item shall be immediately covered or otherwise protected from contamination until packaging or installation.

CHAPTER 18
PROCESS REQUIREMENTS

18.0 CONTAMINATION CONTROL PROCESS REQUIREMENTS

This chapter establishes minimum acceptable contamination control requirements to prevent particulates and other contaminants from degrading the cleanliness of parts, components, and subsystems which can occur as a result of inadequate process controls. Special emphasis is placed on the avoidance of the inadvertant introduction of particulates into parts, components, and subsystems during the cleaning, assembly, functional testing, and packaging processes.

18.1 SOLUTION CONTROLS. Precleaning solutions and especially final cleaning solutions shall be controlled relative to influent and effluent analysis, solution replacement or adjustment, cleaning effectiveness, and compatibility with the type of material being cleaned.

18.1.1 SOLUTION CONTROL RECORDS. Records shall be maintained indicating the scheduled analysis, analysis results, and any solution replacement or adjustment activities.

18.1.2 SOLUTION COMPOSITION. Approved solution compositions may be as established by the using agency or as recommended by the supplier when proprietary solutions are utilized.

18.1.3 SOLUTION ANALYSIS. Approved solution analysis may be as established by the using agency.

18.2 SPECIAL CLEANING PROCESSES. Special cleaning processes such as ultrasonic cleaning and surge cleaning shall be controlled by specific standard operational requirements.

18.2.1 ULTRASONIC CLEANING. Ultrasonic cleaning equipment shall be tested to verify that adequate cavitation turbulence for good cleaning action is being maintained. Such tests shall be conducted using the manufacturer's recommended test method.

18.2.1.1 ULTRASONIC FLUID. The fluid used in ultrasonic cleaning equipment shall be as recommended by the manufacturer. When an alternate fluid is used, tests shall be performed to verify that the alternate fluid does not prohibit proper cleaning action.

18.2.2 SURGE CLEANING. Surge or pressure/vacuum cleaning of components, systems, and pressure vessels shall be subjected to specific pressure/flow controls to prevent damage to the item from pressure or vacuum. Items such as pressure vessels which are sensitive to pressure cycle fatigue shall not be cleaned utilizing a surge cleaning procedure.

18.3 PARTS PRECLEANING PROCESS CONTROLS. Precleaning of parts shall accomplish the removal of all visible contaminants without removing or changing the characteristics of the base material. All traces of precleaning materials shall be removed from parts at the completion of the precleaning process to prevent the future formation of mineral salts and corrosion products. Tests such as pH testing shall be utilized to verify removal of all residuals.

18.3.1 EXTRANEOUS CONTAMINANTS. Extraneous contaminants such as particulates or films shall be minimized to preclude recontamination of the parts following the precleaning process. Process controls shall include, as a minimum, protection of the item by interim packaging or other approved means to prevent recontamination through all subsequent operations.

18.4 PARTS FINAL CLEANING PROCESS CONTROLS. Final cleaning of parts shall accomplish the removal of all visible contaminants without removing or changing the characteristics of the base material. Definitive final cleaning procedures shall be utilized.

18.4.1 PARTS SAMPLING CONTROL. A representative solvent solution sample shall be taken from the cleaned parts and analyzed to meet the specified cleanliness level. Whenever possible, the parts shall be placed in ultra-clean glass containers while sample analysis is being performed.

18.4.2 PARTS DRYING CONTROL. Cleaned parts shall be dried with inert gas such as nitrogen which is filtered to remove detrimental contaminants. Alternate parts drying techniques may be used provided prior approval is granted. Controls such as the use of clean glass enclosures shall be applied to assure that no contaminants are introduced to the clean parts during the drying process.

18.4.3 PARTS VISUAL INSPECTION. Clean, dry parts shall be visually inspected to detect any particulates or other contaminants. Any observed contaminants shall be cause for rejection.

18.5 COMPONENTS PROCESS CONTROLS. Certified clean parts shall be protected from recontamination by utilizing interim packaging or other protection prior to and during assembly operations. Process controls and extreme care is required to prevent the inadvertant introduction of particulates and other contaminants into the parts and components being processed. Components which have been tested using precision filtered service liquid shall be drained and sealed leak tight with clean caps or plugs at all ports. The exterior surfaces shall then be wiped with non-lint producing material moistened with approved, compatible solvent and dried.

18.5.1 COMPONENTS ASSEMBLY CONTROL. Process controls such as the use of purge gases, dry box enclosures, and strict personnel controls shall be established to assure that no contaminants are introduced into the component being assembled. Visual inspection shall be performed frequently during the assembly process to assure that contaminants have not been introduced. Parts and components shall be rejected if visible contaminants are detected during the assembly process.

18.5.2 COMPONENTS FUNCTIONAL TESTING. Components such as valves which require functional testing shall be protected from particulates and other contaminants during the process. When possible, all functional testing shall be performed inside a laminar flow work station. All functional testing equipment such as pressurization consoles and connecting hardware shall be sampled and certified to meet the required cleanliness level. Components suspected of being contaminated beyond the acceptable level during the process shall be rejected, disassembled, and recleaned.

18.5.3 CLEANLINESS VERIFICATION OF FUNCTIONALLY TESTED COMPONENTS. Immediately following functional testing of each component, a sample of the test fluid shall be obtained for analysis to verify that the exercise of the component by testing has not generated debris exceeding the contamination allowable for the system. This may be obtained by draining the component or by flushing. The sample shall be filtered and the residue washed with clean solvent, dried, and evaluated using specific acceptance criteria as applicable to the system.

18.5.4 COMPONENTS PACKAGING. Packaging of components shall be accomplished to minimize contamination from packaging techniques or packaging materials. Process controls shall be established and include certification that the components meet established cleanliness levels.

18.6 SUBSYSTEMS PROCESS CONTROLS. Certified clean components are assembled, while constantly being protected from contaminants, inside laminar flow work stations and other controlled environment facilities to become subsystems. Process controls and extreme care are necessary to minimize the inadvertant introduction of particulates and other contaminants into the components and subsystems being processed.

18.6.1 SUBSYSTEMS ASSEMBLY CONTROL. Process controls shall be established to assure that contaminants are not introduced into the subassembly being assembled. Rejection of the components and subassemblies shall occur if contaminants are detected during the assembly process, and recleaning of components shall be in accordance with Chapter 11. If the subsystem is contaminated, appropriate authorities shall determine whether to disassemble and clean the subsystem or perform in-place cleaning to meet the appropriate cleanliness levels.

18.6.2 SUBSYSTEMS SAMPLING. The fluid or gas effluent used in the subsystem shall be sampled and analyzed to meet the appropriate cleanliness requirements. Appropriate authorities will determine whether to disassemble the subsystem for cleaning when any sample fails.

CHAPTER 19
NONAIRBORNE BREATHING SYSTEMS

19.0 NONAIRBORNE BREATHING SYSTEM

This chapter establishes the minimum cleanliness requirements for nonairborne breathing systems, both portable and permanently installed. Also included are the sampling requirements and sampling frequencies to be maintained during operational and nonoperational periods.

19.1 CLEANLINESS REQUIREMENTS. Parts, components, subassemblies, and assemblies shall be cleaned in accordance with applicable portions of Chapter 11 to a cleanliness level meeting the requirements of Level 5 of Table I.

19.1.1 ALTERNATE CLEANING. If cleaning of an installed system where system volume or configuration requires the use of a nitrogen cleaning media, the nitrogen cleaning and purging operation shall be followed by introduction of the system gas. The system gas shall be flowed until the effluent meets the hydrocarbon requirements of the system gas, and the particulate level meets the requirements of Level 5 of Table I.

19.1.2 CLEANLINESS MAINTENANCE. A matrix of the positive blanket and sample frequency requirements for nonairborne breathing systems is shown by 19.2.10. Compliance with these requirements will assure the integrity of the system/item and will maintain these in a ready state.

19.1.2.1 CONNECTOR CLEANLINESS MAINTENANCE. Ports, open-ended lines, and interconnecting fittings shall be protected during periods of nonuse as required by Chapter 12 or as required by applicable operational documents to maintain fitting cleanliness integrity.

19.2 SAMPLING REQUIREMENTS. The sampling frequencies and schedules delineated herein are considered the minimum acceptable. More stringent sampling frequencies or schedules may be required for specific application. Sampling, inspection, and testing shall be in accordance with the requirements of this document.

19.2.1 SAMPLING METHODS AND EQUIPMENT. The methods for obtaining a representative sample for purity and particulate analyses and the method of preparing and handling sample containers are described in 21.1.10 of Chapter 21.

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19.2.1 SAMPLING METHODS AND EQUIPMENT. The methods for obtaining a representative sample for purity and particulate analyses and the method of preparing and handling sample containers are described in 21.1.10 of Chapter 21.

19.2.2 SAMPLE VOLUME. The volume of the sample shall be of sufficient quantity to perform all of the analyses for the specified system gas. The sample, along with the quality specification limits, shall be forwarded to a laboratory which has the analytical capability of providing standard methods of analysis for gaseous, liquid, or particulate contaminants as applicable.

NOTE: For safety reasons a rigid sample container must have a rated service pressure greater than the pressure at the source. The necessary handling equipment and safety precautions shall be implemented when withdrawing samples from a compressed gas source.

19.2.3 SYSTEM VERIFICATION AND SAMPLING REQUIREMENTS. The system verification and sampling requirements defined herein shall govern nonairborne breathing systems.

19.2.3.1 COMPRESSED GAS SYSTEM. Prior to certifying a compressed gas system for breathing purposes, detailed installation, servicing, maintenance, preventive maintenance, and operating procedures shall be developed and implemented. Provisions must be included for notifying each user of the compressed gas when the compressor has failed, loss of system pressure, or the introduction of contaminants in the system has occurred. In the event of such an occurrence, the use of the system for breathing purposes shall be terminated until the system has been certified again.

19.2.3.2 SAMPLING REQUIREMENTS. The following sampling requirements shall be implemented in the proving of systems for breathing purposes.

19.2.3.2.1 Systems which have not been certified shall be sampled prior to use and once each 24-hour period for the next 48 hours.

19.2.3.2.2 If satisfactory results are obtained, the system shall then be sampled once each 7-day period for the next 14 days at which time, if the results are acceptable, the system may be considered certified.

19.2.3.2.3 Certified systems shall be maintained and sampled in accordance with the schedule shown by 19.2.10.

19.2.3.2.4 EQUIPMENT FAILURE. Certified breathing systems which have experienced compressor failure or malfunction, loss of system pressure, and/or the introduction of contaminants in the system shall be resampled in accordance with 19.2.3.2. Failure to meet the established requirements for proven breathing systems shall require identification of the cause of the anomaly, positive corrective action, and repeated certification of the system according to 19.2.3.2.

CAUTION: When compressed gas for breathing purposes is supplied from a multiple-use or central system, the pressurizing of tanks or vessels containing toxic or flammable liquids and gases shall not be permitted, unless adequate precautions are taken to prevent backflow into the breathing air system.

19.2.4 CYLINDER SUPPLIED COMPRESSED GAS SYSTEMS. Charged gas cylinders used for breathing purposes must be analyzed and the contents certified prior to use.

NOTE: Certifications must include name of supplier and certification of materials supplied which includes proper identification and the analytical results demonstrating conformance to this chapter and CGA 7.1.

19.2.5 MIXED GAS SYSTEM. Each constituent gas which has not been certified must be sampled and the sample analyzed prior to mixing to ensure meeting the requirements of each applicable specification. The synthesized gas must be sampled following the blending process to assure adherence to the requirements of this chapter.

19.2.6 INSTALLATION, MAINTENANCE, AND SERVICING. To be assured a "pure" compressed gas supply a number of detailed installation, operation, maintenance, servicing, preventive maintenance procedures, and safety precautions must be developed. Operation and maintenance logs shall be kept on all compressors and associated compressed gas equipment used in breathing air systems.

19.2.7 COMPRESSED ATMOSPHERIC AIR SYSTEM (DIRECTLY COMPRESSED OR COMPRESSED AIR CYLINDER). Compressor operation and maintenance shall be in strict adherence to the manufacturer's instructions, with specific attention to cooling of compressor chambers, and maintenance of piston rings, driers, filters, and other accessories.

19.2.7.1 A typical installation includes the following.

19.2.7.1.1 The air intake is filtered with HEPA filters.

19.2.7.1.2 Warning or detection devices are installed to indicate cylinder over temperature, low oil pressure, or loss of system air pressure.

19.2.7.1.3 A method is utilized to condense the moisture contained in the air or gas compressed. Such equipment is normally equipped with well-proportioned separators and automatic traps to drain the condensates formed.

19.2.7.1.4 The air receiver or tank is placed in a cool place as close to the compressor as possible. The receiver is of sufficient size to equalize the discharge pulsations, thus providing a steady flow to the service line. A pressure gage and a safety valve is installed on the receiver.

19.2.7.1.5 All filters located downstream of the compressor are of a high efficiency type for removing solids and particulate matter.

19.2.7.1.6 Condensation traps are installed in distribution lines to remove any separated water before it reaches the use-point.

19.2.8 PRESSURIZED OXYGEN-NITROGEN SYSTEMS shall be installed, operated, and maintained according to the manufacturer's instructions.

19.2.9 IDENTIFICATION AND MARKING. Use-point outlets shall be identified by displaying a sign, tag, or label with the following information: "Compressed Gas for Breathing Purposes," MSC Type____; System Pressure (psig); Date of Last Acceptable Test; and Approval Signature. Pressurized Cylinders shall be stenciled, tagged, or labeled with the following information: identification of product, applicable specification number, contract or purchase order number, supplier's identification, lot identification, and fill date.

19.2.10 BLANKET AND SAMPLING REQUIREMENTS FOR NONAIRBORNE BREATHING SYSTEMS

EXHIBIT I

	MAINTAIN 1 PSI POSITIVE PRESSURE DURING PERIODS OF NONUSE	TWO SAMPLE ANALYSIS REQUIRED WITHIN 48 HOURS OF FIRST MANNING	SAMPLE ANALYSIS REQUIRED WITHIN 14 DAYS OF FIRST MANNING	SAMPLE ANALYSIS REQUIRED PRIOR TO EACH MANNED OPERATION	SAMPLE ANALYSIS REQUIRED WITHIN 30 DAYS OF LAST USE AND AT 30 DAY INTERVALS THEREAFTER	SAMPLE ANALYSIS REQUIRED WITHIN 90 DAYS OF LAST USE AND AT 90 DAY INTERVALS THEREAFTER
ENVIRONMENTAL CONTROL SYSTEMS	X	X			X	
FACILITY OXYGEN SYSTEMS	X	X			X	
SUIT CHECKOUT CONSOLES	X	X			X	
RESCUE BOTTLES	X		X			X
BACKPACKS	X					X
PORTABLE OXYGEN VENTILATORS	X		X			X
WALKAROUND BOTTLES	X		X			X
SURVIVAIR PACKS	X					X
CHAMBER SOURCE SUPPLIES				X		
SUIT SOURCE SUPPLIES				X		

CHAPTER 20
SPACECRAFT ON BOARD EQUIPMENT CLEANLINESS

20.0 SPACECRAFT ON-BOARD EQUIPMENT CLEANLINESS

This chapter establishes the minimum cleanliness requirements for portable equipment and supplies brought onboard the spacecraft at any time that spacecraft interior contamination control is being exercised. It includes all GFE (Government-furnished equipment) such as spacesuits, experimental hardware, packaged food, survival equipment, tools, umbilicals, adaptors, and connectors. Methods and procedures for attaining cleanliness levels are not considered within the scope of this chapter but shall be the responsibility of the organization providing the equipment; these methods and procedures, however, must meet the requirements of the referenced documents. Volume 2 of this manual lists the cleanliness levels required for GFE that is taken onboard the spacecraft. The cleanliness requirements defined in Volume 2 are applicable to parts serving identical design and use purposes.

20.1 CLASSES OF EQUIPMENT. Two classes of on-board equipment are recognized.

20.1.1 CLASS A EQUIPMENT. This equipment does not interface with any other spacecraft fluid system. A tool is an example of class A equipment.

20.1.2 CLASS B EQUIPMENT. This equipment interfaces with other fluid systems in the spacecraft. The spacesuit is an example of class B equipment.

20.2 GENERAL REQUIREMENTS. The general requirements defined herein shall govern the cleanliness and handling of on-board equipment.

20.2.1 CLEANING. Detailed methods and procedures are the responsibility of the organization providing the equipment; requirements for cleaning are delineated in Chapter 11, the cleaning materials must be compatible with the item.

20.2.1.1 CLASS A EQUIPMENT. Surfaces exposed to the crew bay environment shall be cleaned to a visibly clean condition (including the absence of visible hydrocarbons). This cleaning shall be accomplished in a clean room or clean work station of class 100,000 or better, as defined in Chapters 6 and 7.

20.2.1.2 CLASS B EQUIPMENT. The internal contaminant-sensitive surfaces are to be cleaned to the same cleanliness level as the contaminant-sensitive surfaces of the fluid system with which they interface. Exterior surfaces of class B equipment shall be cleaned to the cleanliness level stipulated in 20.2.1.1.

20.3 PACKAGING. Packaging materials and methods utilized for on-board equipment shall be in accordance with the requirements of Chapter 12. Items which remain packaged during any portion of the spacecraft flight shall be compatible with the spacecraft atmosphere (GOX). Packaging which will be removed prior to exposure to the cabin flight environment need not be GOX compatible. Packaging materials, especially those used to cover parts of on-board equipment interfacing with fluid systems, shall be chosen to minimize particulate generation.

20.4 PACKAGING REMOVAL. Equipment requiring removal of packaging upon stowage in the spacecraft shall remain in the package until actually in the spacecraft environment (class 100,000, see Chapter 16), or shall remain packaged up to the point of entry. The exterior of any package taken into the spacecraft shall be verified as being visibly clean prior to entry.

CHAPTER 21
FLUID SAMPLING

21.0 SAMPLING

This chapter describes methods of sampling liquids and gases. The constraints implied by sampling, the frequency of sampling, and the techniques of sampling are included. This chapter is neither an operating procedure or job instruction which details the specifics required to perform a sampling operation. Detailed procedures or job instructions are the responsibility of the operating agency and are not within the scope of this document. MSC document MSC-01218 details the preferred methods of sampling and may be used as a guide in establishing detailed procedures.

21.1 SAMPLING REQUIREMENTS. All sampling apparatus shall be cleaned to a level consistent with the operations being performed. If particulate contamination of the sampler is suspected, blank rinses using a precision cleaning solvent filtered through a membrane filter (0.2 to 0.8 micron) shall be run to determine the contaminant level of the sampler. Cleaning of samplers to a particulate level should be limited to those situations where the particle count is required. Cleaning shall be in conformance to the requirements of Chapter 11. Acceptable particulate levels and the recommended use for each level are shown by Table I.

21.1.1 CONTAMINATION CONTROL DURING SAMPLING. Reasonable precautions should be taken to preclude contaminating the sampler, fluid, or system prior to, during, and after the taking of the sample. The sample port on the line (container) to be tested shall be flushed with filtered clean precision cleaning solvent immediately prior to connection of the sampler. Care should be exercised that in cleaning the sample ports, the cleaning solvent does not contaminate the sampler; i.e., such as a chlorinated solvent where the sample will be analyzed for halogenated hydrocarbons. Sample ports shall be properly capped and/or packaged according to Chapter 12.

21.1.2 DYNAMIC SAMPLES. Sampling, where possible, should utilize a closed system (not exposed to the atmosphere). For samples taken during a fill operation, a flow-through sampler should be used at the same flow rate as the system being serviced. Liquid samples should be at least 500 ml. each (2 liters preferred) and gases should

be at least 480 standard liters. Gaseous samples for particulate should be taken with the sampling system operating at the design mass flow rate or, in the event this is not practicable, at a flow rate producing turbulence.

21.1.3 SAMPLER. Materials of construction for samplers must be compatible with the sampled fluids and shall contribute a minimum of contaminants to the sample. Samplers shall be serialized and identifiable as to the material sampled and the sample source.

21.1.4 SAFETY. Safety requirements are not delineated in this chapter since these should be included in the detailed operating procedures which shall reflect the requirements of the cognizant safety organization.

21.1.5 SAMPLE POINTS. Vehicle test points (identified as the "most severe" locations, such as bottom of propellant tank, just upstream of engines, etc.) shall only be sampled when specifically required by controlling documentation. Operational fluids as supplied to the spacecraft shall be sampled as close as possible to the GSE-vehicle interface or as required by system documentation.

21.1.6 PROCURED FLUID SAMPLING. The sampling of procured fluids (number of samples per lot, etc.) is controlled by the applicable procurement specification. It is extremely important to sample stored fluids at regular intervals, and sufficiently before anticipated use, to obtain an alternate supply if the fluid on hand is unacceptable. When containers of liquids are to be sampled which have been at rest so that particles present may have settled out, they shall be agitated prior to sampling to assure a representative sample. Stationary containers, and/or pressurized containers shall not be agitated.

21.1.7 SAMPLING OF HYPERGOLIC PROPELLANTS. The hypergolic propellants include the oxidizer, inhibited nitrogen tetroxide (MSC-PPD-2B) and the fuels, hydrazineunsymetrical dimethylhydrazine (MIL-P-27402) and mono methylhydrazine (MIL-P-27404).

21.1.7.1 SAMPLERS. The sampling apparatus should, as a minimum, comply with the requirements delineated in MSC-01218.

21.1.7.2 VEHICLE LOADING (DYNAMIC SAMPLING). If the fluids are acceptable in NVR (or hydrocarbon) and water content, loading may proceed and the dynamic samples mentioned in 21.1.2 shall be pulled, one at the beginning and one near the end of the loading operation. The provisions of 21.1.1 shall apply.

21.1.7.3 STATIC OPERATIONS. Where flow-through cannot be accomplished, the sampler shall be filled and drained twice prior to retaining a sample. Where safety or other constraints demand, the sampler may be evacuated prior to use. This method, however, provides the least representative sample and should be utilized when no other choice is available.

21.1.7.4 DECONTAMINATION, CLEANING, AND STORAGE OF SAMPLERS. Following analysis of the sampler contents, the sampler is drained, decontaminated, and cleaned to the requirements of 21.1. The sampler is then reassembled, the sample ports covered according to Chapter 12, and the sampler stored before the next sampling. Recommended procedures for decontamination of samplers are delineated in document MSC-01218.

21.1.8 SAMPLING OF CRYOGENIC LIQUIDS. The cryogenic liquids include liquid oxygen (MSFC-SPEC-399A), liquid hydrogen (MSFC-SPEC-356), liquid helium (MSFC-SPEC-364B), and liquid nitrogen (MSFC-SPEC-234A), and should be sampled in accordance with document MSC-01218.

21.1.8.1 SAMPLERS. An approved sampler, similar to the liquid oxygen sampler described in MIL-S-27626A, should be used.

21.1.8.2 SAMPLING. Cryogenic liquids are normally sampled as liquids and analyzed as gases. The provisions of 21.1 through 21.1.6, as applicable, shall apply. Because of sampler construction, samples may have to be of the static (21.1.7.3) type. Sufficient purging or flushing of the sampler shall be allowed to guarantee removal of any trace contaminants.

21.1.8.3 PARTICULATE. Cryogenic samplers such as that described in MIL-S-27626A, are normally not used for particulate samples. Flowing the cryogen through a high pressure membrane bomb (using a Teflon membrane) into a Dewar flask (to measure quantity analyzed) permits a more reliable particulate analysis.

21.1.8.4 CLEANING AND STORAGE OF SAMPLERS. Liquid cryogenic samplers must be maintained in a clean condition because of the rigid purity requirements for the fluids they contain. The provisions of 21.1 shall apply. Heat and vacuum may be used to remove absorbed impurities. Purge gases shall be those of the material normally sampled and shall be of sufficient purity to preclude contaminating the sampler.

21.1.9 SAMPLING OF GASES. The gases include gaseous oxygen (MSFC-SPEC-399A), gaseous nitrogen (MSFC-SPEC-234A), and gaseous helium (MSFC-SPEC-364B).

21.1.9.1 SAMPLERS. Sampler configurations differ because of the pressures of the gases sampled. A "watermelon" is normally used for sampling low pressure gases up to 1800 psig. Samplers shall be used only for one gas.

21.1.9.2 SAMPLING. MSC document MSC-01218 delineates the MSC preferred methods for sampling gases. Applicable provisions of 21.1 through 21.6 shall be observed.

21.1.9.3 PARTICULATE. Gases are analyzed for particulate by tapping a system or storage test point and flowing the gas through a membrane filter. Samples must show a complete "O" ring indentation on the membrane or resampling is required. A high pressure gas membrane filter assembly with an appropriately sized membrane filter is used. Extreme care must be taken in attaching the sample assembly to the sample port since particulate requirements for gases are normally tight, and the making-breaking of mechanical connections can generate particles. The filter assembly is

held vertically so that the particles impinge on the horizontal filter membrane in a downward, vertical flow. The gases should flow through the assembly at the design mass flow rate of that system delivery point or, if impracticable, at a flow rate to produce turbulence. A blank membrane, prepared similar to the test membrane, may have to be used to determine background count.

21.1.9.4 CLEANING AND STORAGE OF SAMPLERS. The provisions of 21.1 apply. A 2-5 psig blanket of the gas sampled should be maintained in the cleaned sampler.

21.1.10 SAMPLING OF BREATHING SYSTEMS. Breathing systems gas includes the mixed gas and oxygen systems.

21.1.10.1 SAMPLERS. High pressure filter holders and high pressure sample bottles are acceptable for sample collection and laboratory analysis if they comply with the following.

21.1.10.1.1 They must be prepared for sampling in accordance with this chapter or MSC-01218 as applicable.

21.1.10.1.2 They must be accompanied by a completed report form.

21.1.10.1.3 They must be capped with proper closures to preclude outside contamination.

21.1.10.1.4 The high pressure filter holder shall be kept in an upright position after sampling and shall be transported to the laboratory using a transporter to maintain the filter holder in an upright position.

21.1.10.1.5 The preparation of the high pressure filter holder and the particulate sample analysis shall be performed in at least a class 10,000 clean room or work station in accordance with Chapters 6 and 7 as applicable.

21.1.10.2 CLEANING OF SAMPLING APPARATUS. Sampling apparatus shall, as a minimum, be cleaned as follows.

21.1.10.2.1 Wash each part of the disassembled sampling apparatus (filter holder, sample bottle, fittings, hoses, etc.) with a hot detergent and water solution.

21.1.10.2.2 Rinse or flush twice with distilled water.

21.1.10.2.3 Rinse or flush twice with isopropyl alcohol.

21.1.10.2.4 Rinse or flush three times with filtered solvent.

21.1.10.2.5 Certify by liquid sample that the required cleanliness of the sampling apparatus has been met.

21.1.10.2.6 Purge dry with filtered nitrogen.

21.1.10.3 PREPARATION AND ASSEMBLY OF FILTER AND HIGH PRESSURE FILTER HOLDER. The preparation and assembly of high pressure filter holders for breathing air sampling shall, as a minimum, be as follows.

21.1.10.3.1 Using clean forceps, remove the filter from its container.

21.1.10.3.2 Pressure rinse the grid side of the filter with a stream of filtered solvent.

21.1.10.3.3 Microscopically examine the filter for holes, gouges, etc. Also, size and count all particles over 10 microns in size. This particle count shall be known as the sample "blank" and shall be recorded.

21.1.10.3.4 Place the filter with grid side up on the lower half of the filter holder.

21.1.10.3.5 Immediately place, do not slide, the upper half of the filter which contains the O-ring into position.

21.1.10.3.6 Install and torque the bolts and closures.

21.1.10.3.7 Seal the clean, assembled high pressure filter holder in a clean polyethylene bag.

21.1.10.4 PREPARATION OF SAMPLE BOTTLE. Subsequent to initial cleaning and certification as delineated in 21.1.10.2 the sample bottle shall not be used for sampling any other fluid. Recleaning is not required for each sampling providing the bottle remains sealed (except when in use) and a preceding sample has not failed. The bottle will be sealed with AN type caps or plugs.

21.1.10.5 PREPARATION OF HOSES, TUBING, AND FITTINGS. Subsequent to cleaning and drying, hoses and tubing shall be sealed with clean AN type plugs and then sealed in clean polyethylene bags. Fittings shall be sealed individually in clean polyethylene bags.

21.1.10.6 PARTICULATE SAMPLING OF BREATHING GASES. This section essentially describes a blowdown sampling method conducted at available pressure for a given length of time. Sampling shall be as follows.

21.1.10.6.1 A properly prepared high pressure filter holder shall be obtained. The sample source(s) shall be identified on a test request form.

NOTE: Before opening any valves or making any connections, ensure that the membrane filter holder will not be subjected to pressure exceeding proof pressure.

21.1.10.6.2 Carefully connect sampling hose, if required, to system sampling connection or valve. Secure the free end of the sampling hose and momentarily purge the sampling hose.

21.1.10.6.3 Remove the caps from the filter holder and carefully attach sampling line to the inlet of the filter holder.

NOTE: For low-pressure breathing systems (3 to 4 psig) a compressor-vacuum pump may be used downstream of the high pressure filter holder to increase flow.

21.1.10.6.4 Connect a calibrated flowmeter downstream of the filter holder and commence flow. Note flow rate and flow time for the test; as a minimum 10 SCF shall be sampled unless otherwise specified.

21.1.10.6.5 Carefully disconnect and cap the membrane filter holder. Transport the filter holder to the laboratory for particle analysis.

21.1.10.7 MICROSCOPIC ANALYSIS OF THE SAMPLE. Microscopic analysis of the sample shall be in accordance with 13.2.14.2.

21.1.10.8 SAMPLING FOR PURITY. A recommended procedure for sampling a pressurized breathing gas is to capture a sample which can subsequently be introduced into appropriate laboratory instrumentation for analysis. A properly prepared sample bottle shall be obtained and sample sources shall be identified on the test request form. Sampling shall be as follows.

NOTE: Before opening any valves or making any connections, ensure that the sample bottle will not be subjected to a pressure exceeding proof pressure.

21.1.10.8.1 Carefully connect a sampling hose, if required, to system sampling connection or valve. Secure connections.

21.1.10.8.2 Remove caps from sample bottle and attach and secure sample bottle.

NOTE: For low-pressure breathing systems, an oil-free compressor-vacuum pump may be used to pressurize the sample bottle.

21.1.10.8.3 Carefully pressurize and depressurize the sample bottle three times. As a minimum, the sample bottle shall be pressurized to 80 psig for an appropriate sample.

21.1.10.8.4 After the third depressurization, again pressurize and close the sample bottle. Carefully disconnect the sample bottle and cap openings.

21.1.10.8.5 Transport the sample bottle to the laboratory for analysis as specified by the test request.

21.1.10.9 EQUIPMENT BLANK DETERMINATION. A blank shall be prepared to determine the number of particles generated by the environment, equipment, and materials on at least 10 percent of the filter holders prepared as specified herein.

21.1.10.9.1 Place enough filtered solvent into a clean, assembled high pressure filter holder to fill it.

21.1.10.9.2 Apply a vacuum to the outlet end of the filter holder.

21.1.10.9.3 Repeat 21.1.10.9.1 and 21.1.10.9.2.

21.1.10.9.4 Scan the entire filtration area of the blank filter disc for particles larger than 40 microns. If particles over 40 microns in size are present, or if the count of an individual size range is greater than 10 percent of an acceptable sample, check the area, materials, and equipment. Correct any deficiencies in these and other factors as required.

21.1.11 SAMPLING OF WATER-GLYCOL, HIGH PURITY WATER, CLEANING, DECONTAMINATION, AND SUBSTITUTE LIQUIDS. These liquids include water-glycol, high purity water, precision cleaning solvent, and various chlorinated solvents and alcohols.

21.1.11.1 SAMPLERS AND SAMPLING. Sampling equipment and the recommended procedures for sampling these fluids are delineated by document MSC-01218. In addition, the provisions of 21.1.1 through 21.1.6 shall be met, where applicable.

21.1.11.2 CLEANING AND STORAGE OF SAMPLERS. The provisions of 21.1.1 through 21.1.6 pertaining to sampler cleaning shall apply.

CHAPTER 22
CERTIFICATION OF CLEAN ROOMS

22.0 CERTIFICATION OF CLEAN ROOMS

This chapter establishes the methods and procedures to be utilized for the certification of clean room facilities. The minimum criteria for the initial establishment of clean room classifications are defined in conjunction with the methods for certification of the established classification.

22.1 CLEAN ROOM CLASSIFICATION. Clean room areas to be utilized for the processing of spacecraft items or items associated with spacecraft, such as flight critical equipment and ground support equipment, shall, as a minimum, comply with the appropriate clean room class as defined in Chapter 6. The classification of new facilities or the reclassification of existing facilities shall be conducted in accordance with this chapter.

22.1.1 FILTERS. The HEPA filters installed shall be certified by the DOP test method as being at least 99.97 percent efficient by volume on the retention of particulate 0.3 micron and larger. Supplier certification in lieu of this test is acceptable.

22.1.1.1 SEAL LEAK TEST. A seal leak test shall be performed on the installed HEPA filters with the air handling system operated at a required airflow of 90±20 feet per minute on laminar applications or on a 15 to 20 air change per hour basis on nonlaminar flow applications.

22.1.1.2 SEAL TEST PROCEDURE. Using an appropriate linear airflow measuring device, traverse each sealing edge of each installed filter holding the device 3 to 5 inches from the seal. The airflow which is normal to the filter edge should show no variation in excess of ±5 feet per minute. In the event a variation in excess of the ±5 feet per minute is detected, tighten the filter clamps and retest the suspect seal area. Seal leak tests should be performed at a rate not to exceed 10 feet per minute.

22.1.2 FILTER LEAK TEST. Filter leak test certification may be conducted using the DOP aerosol or "smoke" test or may be conducted utilizing an appropriate linear airflow measuring device.

22.1.2.1 AIRFLOW LEAK TEST. Using an appropriate linear airflow measuring device traverse the face of each installed HEPA filter recording the high and low flow readings for each pass on each filter. The measuring device shall be traversed across the filter face at a rate not to exceed 10 feet per minute. The test pattern for the passes on each filter shall each be approximately 2 inches in both a horizontal and vertical plane. A variation from the normal in excess of ±20 feet per minute or an overall variation of more than 25 feet per minute on a single filter is cause for rejection.

22.1.2.2 AIRFLOW CERTIFICATION. Upon successful completion of the airflow leak test described in 22.1.2.1 the room airflow may be approved provided a flow of 90±20 feet per minute is established for laminar flow rooms or the room air changes calculate to be 15 to 20 changes each hour in conventional flow rooms.

22.1.3 PARTICULATE SAMPLING. Particulate sampling of the clean room atmosphere shall be conducted to determine the number of particles in the range of 0.5 micron to 5.0 microns and the number of particles larger than 5.0 microns. These samples shall be obtained while the planned room population is present and with a simulated amount of equipment, tools, fixtures, and parts in the room. The results of these samples shall be compared to the particulate distribution table in Chapter 6.

22.1.3.1 INTERIM CERTIFICATION. Interim certification of the clean room class shall be granted based on the results of the class established by the comparison required in 22.1.3.

22.1.3.2 FINAL CERTIFICATION. Particulate sampling of the "interim certified" clean room shall be conducted on a daily basis to verify the capability of the clean room to maintain the established classification. Acceptable particulate levels in both particle size ranges during normal work activity on three consecutive days shall be considered justification for permanent certification.

22.1.3.3 RECLASSIFICATION. When a clean room facility is to be upgraded to the next higher (cleaner) classification, the particulate sampling procedure as described in 22.1.3, 22.1.3.1, and 22.1.3.2 shall be followed to establish and certify the higher classification.

CHAPTER 23
CLEANING OF GAGES AND SENSING DEVICES

23.0 CLEANING PRESSURE GAGES AND PRESSURE SENSING DEVICES

This chapter establishes procedures and materials to be employed in the precision cleaning of pressure sensing gages and other pressure sensing devices for use in fluid systems. For bellows type, delicate vacuum gages, or very low pressure bourdon tube gages extreme care must be exercised to avoid damage. An acceptable method for cleaning and certifying these is shown by section 23.5 of this chapter.

23.1 PROCEDURES. The procedures outlined herein shall be utilized for the cleaning of pressure sensing devices.

23.1.1 ENVIRONMENTAL REQUIREMENTS FOR GAGES. All final sampling, drying, and inspection operations shall be accomplished within a clean room or clean work station according to Chapter 6 or 7. Generally, for most gages a class 100,000 environment is adequate. Initial cleaning may be accomplished in a noncontrolled environment.

23.1.2 HANDLING OF GAGES. Clean plastic or rubber gloves shall be worn during all solvent cleaning operations. Clean, low-lint, white nylon or neoprene rubber gloves shall be worn when handling cleaned gages. Care shall be taken not to recontaminate gages.

23.1.3 CLEANING EQUIPMENT. Figure 1 provides a recommended schematic for the design of cleaning equipment. Identical compliance to the schematic is not required; however, the cleaning equipment shall essentially provide the functions as described by the schematics and procedures herein.

23.2 CLEANING PROCEDURE. REFERENCE FIGURE 1.

23.2.1 Mechanically clean the gage's screw thread surfaces visually clean using nylon brushes and solvent (MSFC-SPEC-237A).

23.2.2 Assure that valves "A," "B," "C," and "D" are closed.

23.2.3 Mount the gage to be cleaned in the almost flat 2 to 3 degrees above horizontal position with the gage's dial face up.

PRESSURE SENSING GAGE CLEANING ASSEMBLY

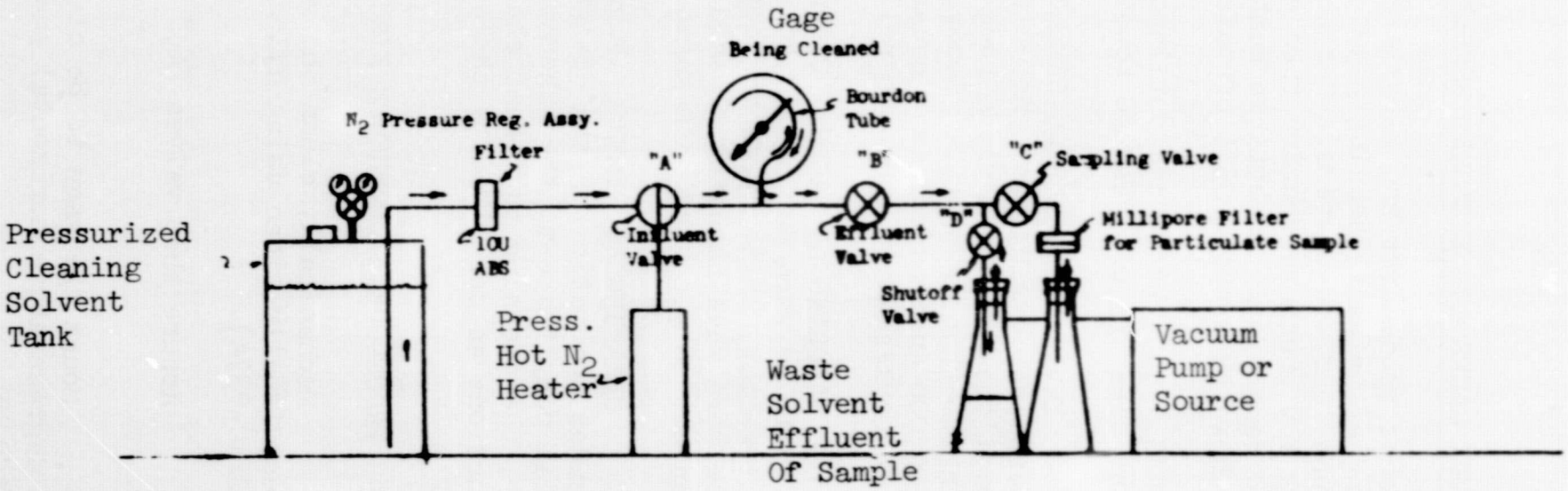


FIGURE I

NOTE: This is the optimum position for assuring rapid and complete flushing of particulate and fluid contaminants from the bourdon tube's critical interior surfaces.

23.2.4 Fill the pressurized cleaning solvent tank with filtered solvent (MSFC-SPEC-237A) and apply a regulated 10 psig of nitrogen gas (MSFC-SPEC-234A).

NOTE: For gages of 25 psi and less, adjust nitrogen pressure downward consistent with the working pressure of the gage to be cleaned.

23.2.5 To fill and flush the system with solvent open valves "A," "B," and "D" and allow 100 to 300 ml. of solvent to flow to waste solvent effluent.

23.2.6 Close valve "D."

23.2.7 Open valve "C" and flow 100 to 200 ml. of solvent effluent to waste.

23.2.8 Close valve "C" and carefully insert a precleaned and precounted membrane filter into the filter holder.

23.2.9 Close valve "A."

23.2.10 Open valve "D" and apply maximum vacuum available to the system.

NOTE: Cleaning of the component begins at this point.

23.2.11 Open valve "B" and leave open 3 to 5 seconds.

23.2.12 Close valve "B."

23.2.13 Open valve "A" and leave open 3 to 5 seconds.

23.2.14 Close valve "A."

23.2.15 Open valve "B" and leave open 3 to 5 seconds.

23.2.16 Continue the opening and closing of valves "A" and "B" for 20 to 50 cleaning cycles.

NOTE: Most gages will meet cleanliness specifications after the above range of cleaning cycles are performed.

23.3 SAMPLING PROCEDURE. REFERENCE FIGURE 1.

23.3.1 Close valve "D."

23.3.2 Open valve "C."

23.3.3 Cycle valves "A" and "B" 10 times each in the manner performed during the cleaning cycle.

23.3.4 Open valves "A" and "B" until a minimum of 100 ml. effluent solvent has flowed through the membrane filter.

23.3.5 Close valves "A," "B," "C," and "D."

23.3.6 Vent pressure and vacuum.

23.3.7 Remove the membrane filter and place it in a clear petri dish with cover and perform the particle count analysis.

23.3.8 Remove the 100 ml. effluent solvent sample and perform the NVR analysis.

NOTE: If the samples do not meet cleanliness specifications repeat the cleaning and sampling cycles.

23.4 DRYING PROCEDURE. REFERENCE FIGURE 1.

23.4.1 Open valves "A," "B," and "D."

23.4.2 Dry with a hot (120° to 140°F.) nitrogen gas (MSFC-SPEC-234A) purge for 3 to 5 minutes.

23.4.3 Close valve "A."

23.4.4 Regulate the hot nitrogen gas to 10 psig.

23.4.5 Apply maximum vacuum to the system.

23.4.6 Cycle the hot nitrogen gas 5 minutes by opening and closing valves "A" and "B" in the regular manner.

23.4.7 Remove pressure and vacuum from the system.

23.4.8 Remove the gage from the system. The threaded area of the gage shall be cleaned to a visibly clean level.

23.4.9 Precision clean package the gage immediately according to Chapter 12.

23.5 CLEANING PROCEDURE FOR FRAGILE GAGES. This procedure is for cleaning bellows type gages, very low pressure bourdon tube gages, vacuum gages, and other fragile dead-ended type components.

23.5.1 Disassemble as necessary to preclude damage of component parts and to aid cleaning of all critical surfaces.

23.5.2 Rinse critical surfaces with clean, filtered solvent (MSFC-SPEC-237A).

23.5.3 Obtain a solvent rinse sample and perform the particle count and NVR analysis. Repeat rinsing until cleanliness specifications are met; dry and reassemble as applicable.

23.5.4 Precision clean package the gage according to Chapter 12.

NOTE: Gages shall be cleaned to a cleanliness level equal to or better than the cleanliness level of the fluid system into which the gage is to be installed. Normally, this precision cleanliness requirement (particulate and NVR) shall be entered on the cleaning request form and cleanliness shall be certified to that level. When a gage is to be cleaned for installation in a fluid system which has no precision cleanliness requirement to maintain, the gage may be cleaned according to the procedure herein; however, sampling procedures herein and verification according to 23.3.7 and 23.3.8 are not required. In this case, cleaning only by this specification shall be certified; no certification to a precision clean level will be made.

23.6 ALTERNATE CLEANING PROCEDURE. REFERENCE FIGURE II.

23.6.1 Mechanically clean the gage's screw thread surfaces visually clean using nylon brushes and clean filtered solvent (MSFC-SPEC-237A).

23.6.2 Place the gage to be cleaned inside the bell jar as shown in Figure II.

23.6.3 Open valve "A."

PRESSURE SENSING GAGE CLEANING ASSEMBLY

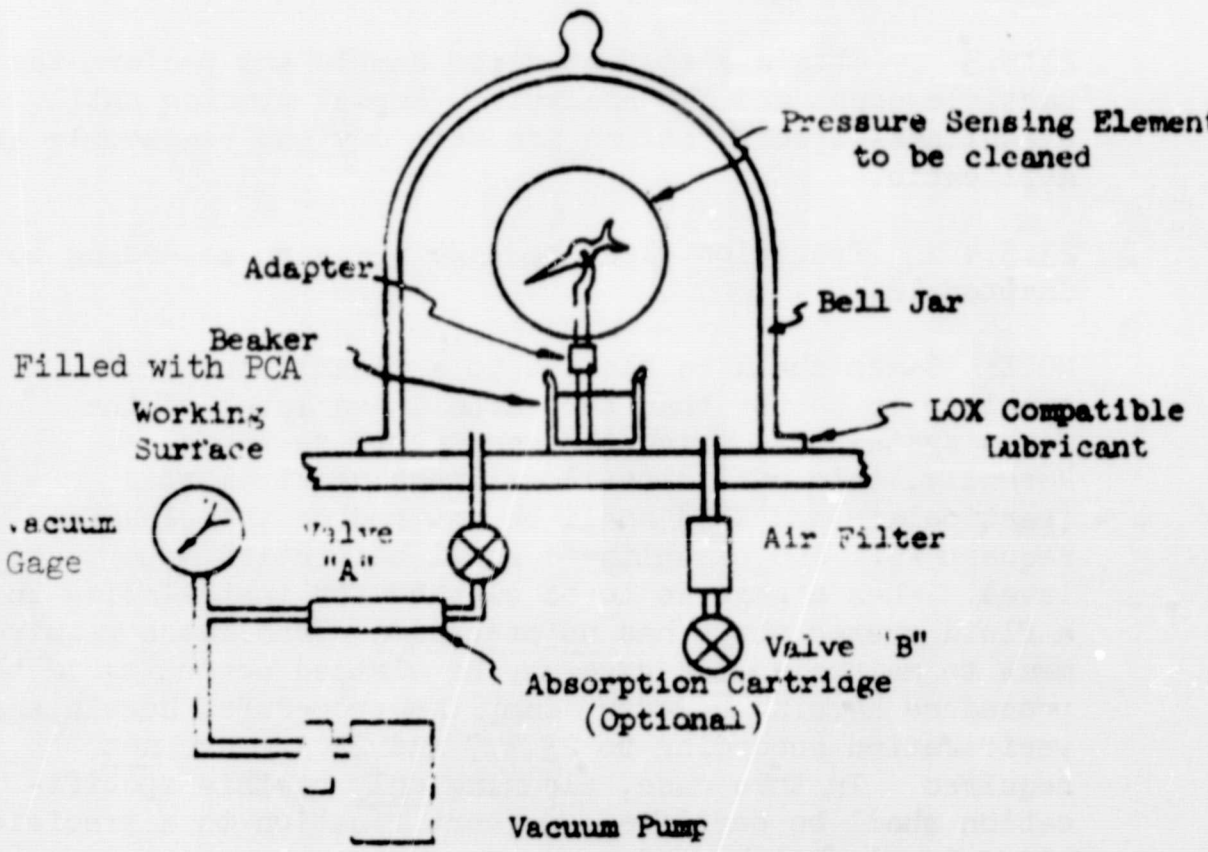


FIGURE II

23.6.4 Close valve "B."

23.6.5 Start the vacuum pump and evacuate the bell jar until the MSFC-SPEC-237A solvent boils.

23.6.6 Close valve "A."

23.6.7 Open valve "B" to admit atmosphere.

23.6.8 Continue the opening and closing of valves "A" and "B" for 20 to 50 cleaning cycles.

23.6.9 Change the cleaning solvent frequently during the cleaning period.

23.6.10 Change the position of the gage being cleaned frequently during the cleaning period.

23.7 ALTERNATE SAMPLING PROCEDURE. REFERENCE FIGURE II.

23.7.1 Cycle valves "A" and "B" 10 times in the manner performed during the cleaning period.

23.7.2 Remove vacuum.

23.7.3 Shake the last drops of solvent from the gage into the effluent sample.

23.7.4 Remove the effluent solvent and perform the particle count and NVR analysis.

NOTE: If the sample does not meet cleanliness specifications repeat the cleaning and sampling cycles.

23.8 ALTERNATE DRYING PROCEDURE.

23.8.1 Dry the gage in a vacuum oven with 26 inches of mercury minimum at 120-140°F. for 2 hours maximum.

23.8.2 Allow the gage to cool at least 15 minutes.

23.8.3 Cap and precision package the gage immediately.

CHAPTER 24
CLEAN ROOM TOOLS

24.0 CLEAN ROOM TOOLS

Clean room tools and tools used in clean work stations and controlled work areas shall be procured, cleaned, used, and maintained in accordance with the requirements of this chapter.

24.1 GENERAL REQUIREMENTS. Tools used in general clean room activities for spacecraft operations, or in work associated with flight equipments, shall be of a type treated to resist corrosion and shall be constructed of minimum particulate generating materials.

24.2 PROCUREMENT. Tools procured for use in contamination control applications shall be standard high quality tools. Tools similar to those supplied through GSA channels are considered acceptable. Certain ultraclean operations may require the procurement of specially constructed or finished clean room tools. Prior to procurement of these special tools the requirements should be carefully reviewed to determine that a genuine need exists as the cost of these can be many times the cost of standard tools.

24.3 DESIGN OR TYPE. Tools with serrated jaws, adjustable features, or mechanical action shall not be procured or used for operations in clean rooms, clean work stations, or controlled work areas unless no other design is feasible. In the event tools with adjustable features or mechanical action must be procured for or used in clean rooms, clean work stations or controlled work areas, the tool selected shall be capable of being disassembled for cleaning. When tools with serrated jaws must be used a padding material shall cover the serrations to prevent the abrasion of parts and the generation of particles.

24.3.1 STRAP WRENCHES. The use of strap wrenches in clean rooms and clean work stations shall be prohibited except in those cases where no other tool can be used. Strap wrenches shall be cleaned, used, and then removed from the clean area. Strap wrenches shall not be kept in the clean room as a standard tool.

24.4 CLEANLINESS. All tools shall be cleaned to a visibly clean condition prior to entry to the clean room, clean bench, or controlled work area. Each tool shall be examined prior to each use to verify that the visual clean condition has been maintained. Tools with cracks, chips, or evidence of corrosion shall be removed from the area and the discrepancy remedied prior to further use in the clean facility.

24.5 MAINTENANCE AND STORAGE. Tools utilized in clean areas shall not be stored in wooden, felt lined, or leather containers. Tools may be stored on stainless steel racks or on clean polyurethane wipes. All tools shall be maintained in a visibly clean condition at all times.

CHAPTER 25

ULTRACLEANING

25.0 ULTRACLEANING REQUIREMENTS

This chapter prescribes controls which are required, either individually or in combination, to attain and maintain cleanliness levels which are more stringent than those described in Table I. These requirements are applicable to items which are extremely sensitive to particulate contaminants as well as items which require very low and carefully controlled TOC (Total Organic Contaminant) levels.

25.1 REQUIREMENTS. Ultracleaning, when specifically required, shall be performed subsequent to precision cleaning operations as described in Chapter 11. The cleanliness to be attained and maintained shall be in accordance with the requirements established by the cognizant design or using organization.

25.1.1 ENVIRONMENT. Operations performed subsequent to the initiation of ultracleaning shall, as a minimum, be in a class 100 atmosphere as defined by Chapter 6 of this manual or FED-STD-209A.

25.1.2 PARTICULATE CLEANLINESS. Items being processed shall be protected by interim packaging during all nonoperational periods.

25.1.2.1 CLEAN ROOM GARMENTS. All personnel involved in operations during and subsequent to the initiation of ultracleaning operations shall be fully attired in clean room garments as described in Chapter 10.

25.1.2.2 FLUSH, TEST, REFEREE FLUIDS. Fluids used for flush, test, or referee purposes shall be certified prior to use. Particulate levels and chemical composition shall be commensurate with the ultracleanliness level to be achieved.

25.1.3 TOC (TOTAL ORGANIC CONTAMINATION) CLEANING. Items to be cleaned to low TOC levels must first be precision cleaned to Level 2 of MSC-SPEC-C-11A (Table I, level 2, of this manual). The items are then immersed in a 3 to 1 ratio of benzene to methanol solution observing adequate safety precautions due to the hazards associated with the use of benzene and methanol. The benzene/methanol is removed in the final cleaning station

using an initial flush of PCA (precision cleaning agent) and ultrasonics. Final flushing is accomplished with freshly distilled PCA. The final flush PCA shall not exceed the following parameters (per 100 mls.):

Particle Count	NVR*	TOC**
10 - 25 = 15	0.2 mg.	2μg.
25 - 50 = 2		
50 - 100 = 1		
>100 = 0		

*NVR - Nonvolatile residue as determined by ASTM-D-2109-64.

**TOC - Total Organic Contamination as determined by gas chromatograph.

The final flush shall have no more than 10μg. (micrograms) per square foot of critical surface maximum TOC with the desired value being 1.0μg. per square foot.

25.1.3.1 GLOVES. Items cleaned to low TOC levels must ONLY by handled with teflon gloves or overgloves cleaned to the TOC levels established herein.

25.1.3.2 DETERGENT. Detergents used for TOC precleaning must be of a composition which will not leave an organic residue after cleaning. Alconox is an example of an approved detergent. Other detergents must have the approval of the organization requiring the TOC cleaning prior to use.

25.1.3.3 FLUSH FLUIDS. The benzene and methanol, used to lower the TOC, must contain no interferring substance greater than that equivalent to 10 parts per trillion of a chlorinated pesticide with a maximum of 0.05 percent water. Nano grade solvents are examples of pesticide free fluids. The PCA used for flushes must have a purity of at least 99.9 percent.

25.1.3.4 LUBRICATION. Post cleaning lubrication of items where required shall consist of MDS (molybdenum-disulfide). The MDS may either be applied dry or as a suspension in a solution of triple distilled water and absolute alcohol.

25.1.3.5 COMPONENT CLEANLINESS. Components must be disassembled to eliminate any mated parts prior to the start of TOC cleaning. These items must be reassembled after cleaning in a clean room environment with the technicians using gloves as defined in 25.1.3.1. Mated parts will be lubricated as set forth in 25.1.3.4.

25.1.3.6 PACKAGING. Cleaned items must be sealed and double bagged in teflon bags which have been cleaned to the same TOC level as the items.

Note 1 - Teflon requires higher heat to seal than does polyethylene or nylon.

TABLE I

CLEANLINESS LEVELS

LEVEL	SIZE RANGE	QUANTITY (MAXIMUM)[1]	NVR PER SQUARE FOOT OF CRITICAL SURFACE AREA (MAXIMUM)[3]	SUGGESTED USE
1	0-5 microns	Unlimited[2]	1 mg.	Pressurization Systems Reaction Control Propellant Systems
	5-15 microns	170		
	15-25 microns	100		
	25-50 microns	40		
	50-100 microns	20		
	> 100 microns	0		
2	0-10 microns	Unlimited[2]	1 mg.	Electrical Power Systems
	10-25 microns	100		
	25-50 microns	10		
	50-100 microns	5		
	100-175 microns	1		
	> 175 microns	0		
3	0-5 microns	Unlimited[2]	1 mg.	Small Propulsion Systems
	5-15 microns	Unlimited[2]		
	15-25 microns	Unlimited[2]		
	25-50 microns	2100		
	50-100 microns	100		
	100-250 microns	4		
	> 250 microns	0		
4	0-25 microns	Unlimited[2]	1 mg.	Main Propulsion Systems
	25-50 microns	1000		
	50-100 microns	100		
	100-180 microns	20		
	180-350 microns	5		
	> 350 microns	0		
	Fibers:			
	< 350 microns	5		
	> 350 microns	0		
5	0-175 microns	Unlimited[2]	1 mg.	Environmental Control Systems
	175-700 microns	6 (particles and fibers)		
	> 700 microns	0 (particles only)		
	Fibers:			
	700-1500 microns	1		
	> 1500 microns	0		

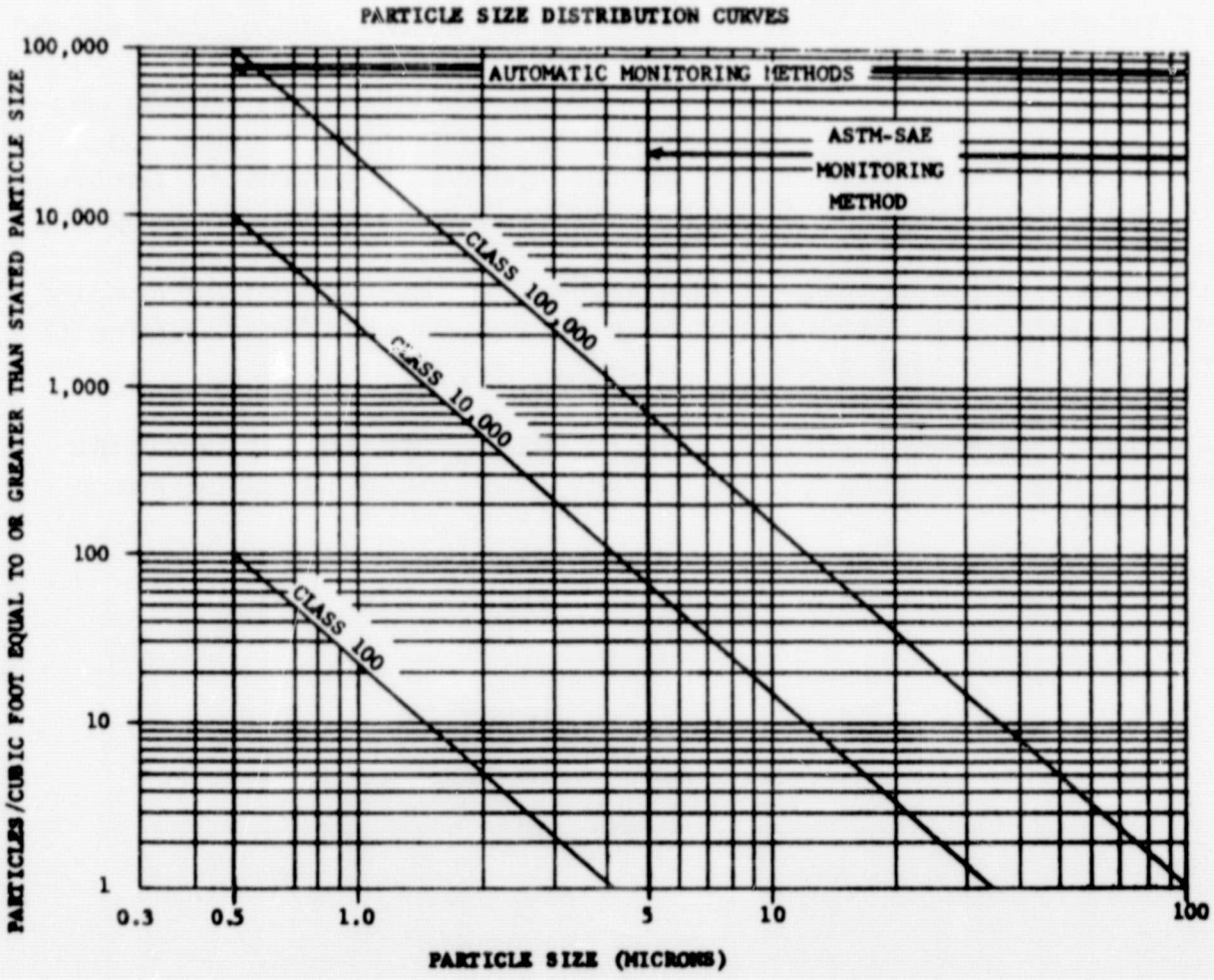
TABLE I NOTES

1. Particulate and NVR allowables are based on the use of 100 ml. of flush fluid per square foot of critical surface area with a minimum sample volume of 500 ml. The minimum volume of 500 ml. is required where sampling valves must be opened and closed to provide an optimum dispersion of the operation generated particulate. In addition, the 500 ml. sample is required when sampling systems, portions of systems, or assemblies. Smaller sample volumes may be used when extremely small items are being sampled and full wetting/flushing may be attained as on systems where the larger sample volume would deplete the supply.

2. Unlimited means particulate in this size range is not counted; however, any obscuring of the filter grid lines is cause for rejection.

3. NVR is not a requirement for fuel systems.

TABLE II



NOTE A: Counts below 10 particles per cubic foot are unreliable except when a large number of samplings is taken.

Class 100

Particle count per cubic foot of air not to exceed a total of 100 particles of a size 0.5 micron and larger and not more than 1 particle 4.0 microns and larger.

Class 10,000

Particle count per cubic foot of air not to exceed a total of 10,000 particles of a size 0.5 micron and larger, 65 particles of a size 5.0 microns and larger and not more than 1 particle 35 microns and larger.

Class 100,000

Particle count per cubic foot of air not to exceed a total of 100,000 particles of a size 0.5 micron and larger, 700 particles of a size 5.0 microns and larger and not more than 1 particle 100 microns and larger.

TABLE III

CLEAN ROOM CLASSES

VS

EQUIPMENT CRITICAL

SURFACE CLEANLINESS LEVELS

CLASS OF[1] CLEAN ROOM	DRESS	EQUIPMENT CRITICAL SURFACE PARTICULATE LEVEL	OPERATIONS/HARDWARE
100 (Note 2)	Suits	10 microns	Guidance and control assemblies
	Caps		Miniature contacts, bearings, optics
	Boots		Miniature gyros
	Gloves		Some hydraulic components
			Critical measurement equipment (particle counting)
10,000 (Note 3)	Suits		Some instruments
	Caps	10-50 micron range	Larger bearings, gyros
	Boots		Small missile components
	Gloves		Large tolerance actuators, regulators and other hydraulic, pneumatic, and LOX system components
100,000	Smocks		Instruments; some gyros
	Caps	50 microns	Electronic components
	Boots		Precision measuring equipment Pneumatic, hydraulic and oxygen systems; LOX components Engine pumps, actuators Missile overhaul

NOTE 1 - Clean room class shall be verified as delineated in 6.3.

NOTE 2 - This class is minimum for items having clearances less than 100 millionths of an inch (2.5 microns).

NOTE 3 - This class is minimum for items having clearances from 100-1000 millionths of an inch (2.5 to 25 microns).

TABLE IV

CLEAN ROOM UNIT OPERATIONS CERTIFICATION RECORD

NAME	CLEAN ROOM ENTRY	PRECISION CLEANING	PART ASSEMBLY	TESTING	SAMPLING	ANALYSIS

APPLICABLE DOCUMENTS

APPENDIX A

DOCUMENTS APPLICABLE

TO MSCM 5322

SPECIFICATIONS

Manned Spacecraft Center

MSCM-8080.2A	Manned Spacecraft Criteria and Standards Program
MSC-Standard 63	Metals and Metal Couples - Restriction on Use
MSC-01218	MSC Standard Procedures for Liquid and Gas Sampling
MSC-PPD-1	Solvent, Trichloromonofluoromethane
MSC-PPD-2B	Propellant, Inhibited Nitrogen Tetroxide
MSC-SPEC-C-20A	Water, High Purity and Distilled
MSC-SPEC-SD-W-0020	Potable Water Specification

George C. Marshall Space Flight Center

MSFC-SPEC-234A	Nitrogen - Space Vehicle Grade
MSFC-SPEC-237A	Solvent, Precision Cleaning Agent
MSFC-SPEC-356	Hydrogen, Liquid
MSFC-SPEC-364B	Helium
MSFC-SPEC-399A	Oxygen
MSFC-SPEC-456	Film, Transparent, Plastic, LOX Compatible, Gas and Contamination Barrier

Military

MIL-A-18455	Argon, Technical
MIL-E-17555	Electronic and Electrical Equipment and Associated Repair Parts, Preparation for Delivery of

MIL-G-4343B	Grease, Pneumatic System
MIL-H-5606B	Hydraulic Fluid, Petroleum Base, Aircraft, Missile, and Ordnance
MIL-L-6086B	Lubricating Oil, Gear, Petroleum Base
MIL-O-27210D	Oxygen, Aviator Breathing, Liquid and Gas
MIL-P-116D	Preservation, Methods of
MIL-P-007936	Parts and Equipment, Procedures for Packaging of
MIL-P-27401B	Propellant, Pressurizing Agent, Nitrogen
MIL-P-27402	Propellart, Hydrazine-uns-Dimethylhydrazine
MIL-P-27404	Propellant, Monomethylhydrazine
MIL-S-27626A	Sampler, Liquid Oxygen, TTU 131/E
MIL-T-27602	Trichloroethylene
AFM 71-1	Air Force Procedures Manual

Federal

FED-STD-209A	Clean Room and Work Station Requirements, Controlled Environment
FED Test Method Standard 791	Fluids, Distillation Range of
O-E-670B	Ethanol, Grade II, Class A
O-H-795	Hydrofluoric Acid, Technical
O-M-232D	Methanol (Methyl Alcohol) Grade A
TT-I-735A	Isopropyl Alcohol
PPP-T-66	Type I, Class B - TAPE: Pressure Sensitive Adhesive Waterproof - For Packaging and Sealing
T. O. 00-25-203	Standards and Guidelines for the Design and Operation of Clean Rooms and Work Station

Nongovernmental
American Society for Testing and Materials

ASTM D512-67	Test for Chloride Ion in Industrial Water and Waste Water

ASTM D891-59	Specific Gravity of Industrial Aromatic Hydrocarbons
ASTM D1125-64	Test for Electrical Conductivity of Industrial Water and Industrial Waste Water
ASTM D1179-61	Test for Fluoride Ion in Industrial Water and Industrial Waste Water
ASTM D1246-55	Test for Iodide and Bromide Ions in Industrial Water
ASTM D1292-63	Test for Odor in Industrial Water and Industrial Waste Water
ASTM D1293-62T	Test for pH of Industrial Water and Industrial Waste Water
ASTM D1429-60	Specific Gravity of Industrial Water and Industrial Waste Water
ASTM D1590-60	Method of Test for Surface Tension of Industrial Water and Industrial Waste Water
ASTM D2109-64	Nonvolatile Matter in Halogenated Organic Solvents and Their Admixtures
ASTM D2111-62T	Specific Gravity of Halogenated Organic Solvents and Their Admixtures
ASTM F25-63T	Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust Controlled Areas Designed for Electronic and Similar Applications
ASTM F50-65T	Tentative Method of Test for Continuous Counting and Sizing of Airborne Particles by the Light Scattering Principle Designed for Electronic and Similar Application
ASTM F51-65T	Tentative Method for Sizing and Counting Particulate Contamination in and on Clean Room Garments
SAE-ARP-598	SAE Aerospace Recommended Practice for the Determination of Particulate Contamination of Hydraulic Fluids by the Particle Count Method

SAE-ARP-743 — Procedure for the Determination of Particulate Contamination of Air in Dust-Controlled Spaces by the Particle Count Method

Compressed Gas Association 7.1 - Compressed Gas Association Operations Manual

MSCM 5322
Volume II

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MSC
CONTAMINATION CONTROL PROGRAM
REQUIREMENTS
MANUAL
VOLUME II

GOVERNMENT FURNISHED EQUIPMENT
CLEANLINESS REQUIREMENTS

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

SEPTEMBER 1970

TABLE OF CONTENTS

1.0 GOVERNMENT-FURNISHED EQUIPMENT CLEANLINESS

This volume establishes the minimum cleanliness and packaging requirements for GFE (Government-furnished equipment). Cleanliness levels described herein shall not supersede any more stringent requirements that may be required from a medical, biological, or system standpoint.

The intent and purpose of this list is to aid in the verification that GFE is cleaned and packaged equal to or better than the minimum requirements.

2.0 APPLICABLE CHAPTERS.

The following chapters of Volume I are applicable to the extent indicated herein.

Chapter 2.0	Definitions
Chapter 20.0	Spacecraft Onboard Equipment Cleanliness
Chapter 12.0	Precision Clean Packaging

3.0 DEFINITIONS.

Chapter 2 of Volume I lists definitions used in the MSC Contamination Control Program. This chapter shall govern the definitions required when interpreting other specifications referenced in this listing.

4.0 REQUIREMENTS.

4.1 The minimum cleanliness levels described shall be verified prior to the introduction of an item to the spacecraft. This verification may be by visual observation, verification of presence of supplier certification, or by physical testing, as applicable.

4.2 Packaging of stowed items shall, as a minimum, comply with the requirements of Chapter 12. This packaging may be removed at the time of spacecraft entry, if required.

4.3 Items which are not specifically listed in this general listing shall be cleaned to the cleanest level specified for items in the same general classification.

TABLE I

CLEANLINESS CODE	CHAPTER	REQUIREMENT
1	20	Surfaces exposed to the crew bay shall be cleaned to a visibly clean condition (including the absence of visible hydrocarbons). This cleaning shall be accomplished in a class 100,000 area.
2	20	The internal contaminant-sensitive areas shall be cleaned to the same cleanliness level as the fluid system with which they interface. External surfaces shall be cleaned to cleanliness code 1.
3		Refer to applicable garment specification for cleanliness and cleaning requirements.
4		Refer to applicable life support specification for cleanliness and cleaning requirements.

EQUIPMENT	PART NAME	CLEANLINESS CODE	APPLICABLE CHAPTER
Breathing Apparatus	CO_2 Absorber	2	20
	Shim CO_2 Absorber	2	
	Oxygen Purge System	2	
	Cable Power	1	
	Cable CCU and Spare	1	
	Power Cable WMS	1	
	Cable Grounding	1	
	Power Cable	1	
Camera Equipment	Cameras, Data Acquisition	1	
	Data Acquisition Magazine	1	
	Lenses and covers	1	
	Mirror, Right Angle	1	
	Cameras, Electrical	1	
	Camera Magazines	1	
	Camera Filters	1	
	Magazine Bags	1	
	Cameras	1	
	Camera Lenses	1	
	Camera Handles	1	
	Camera Hooks	1	
	Camera Lanyards or Straps	1	
	Camera Filter Assemblies	1	
Caps, Covers	Meter Covers	1	
	Meter	1	
	Pressure Caps	2	
	Dust Caps	1	
Clamps	Hose Clamps	1	
Clothing	Coverall, Inflight	1	
	Jacket Assembly	1	
	Trouser Assembly	1	
	Boot Assemblies	1	
	Roll-on Cuffs	1	
	Gloves	1	
	Dual Life Vests	1	
	Constant Wear Garments	1	
Communication Equipment	Container Head, Communication Control Units	1	
	Container Communication Control Unit, Control Head	1	

EQUIPMENT	PART NAME	CLEANLINESS CODE	APPLICABLE CHAPTER
Containers	Temporary Stowage	1	20
	Window Shades	1	
	Pouches	1	
	Sea Water Pump	1	
	Urine Hose	1	
	Stowage Containers	1	
	Container Guards	1	
	Stowage Bags	1	
	Cannisters	1	
	Urine Collection Assembly	1	
	Emesis Bags	1	
Coupling Assemblies, Quick Disconnects	Coupling Assemblies	2	
	Quick Disconnects	2	
Crew Accessories	pH Paper Dispenser Assemblies	1	
	Garments, Constant Wear	3	
	Garments, Liquid Cooled	4	
	Shield, Helment Protective	1	
	Pads, Head Rest	1	
	Chronographs	1	
	Watchbands	1	
	Pens, Data Recording	1	
	Pens, Marker	1	
	Pencils	1	
	Helmet, Pressure Assembly	4	
	Pocket, Checklist and Scissors	1	
	Pocket Checklist	1	
	Biobelt Assemblies	1	
	Utility Towel Assemblies	1	
	Visor Assemblies	1	
	Eyeguard Assemblies	1	
Cushions	Cushions	1	
Data Storage Equipment	Data Storage Equipment	1	
Docking Equipment	Docking Probes	1	
	Adapter Docking Targets	1	
	Docking Drogues	1	

EQUIPMENT	PART NUMBER	CLEANLINESS CODE	APPLICABLE CHAPTER
Electrodes and Electrical Equipment	Electrode Bag	1	20
	Electrode Assemblies	1	
	Micropore Disc Electrode Covering	1	
	Electrode Paste	1	
	Electrode Assembly Attachment	1	
	Electrode Bag Assembly	1	
	Power Supply DC Converter	1	
	Adapter, CWG-Electrical	1	
	ACA Shorting Plug	1	
	Mechanical Simulators	1	
Exercisers	In-flight Exercisers	1	
Filters	Filter Assemblies	2	
	Filters	2	
Fire Protection Apparatus	Fire Extinguishers	1	
Food and Feeding Accessories	Items, Food, and Hygiene	1	
	Food Packages	1	
	Pouches Food Retainer	1	
	Food Assemblies	1	
Guards	Guards	1	
Harnesses	Sternal	1	
	Auxiliary	1	
		1	
Hoses	Hose Assemblies	1	
Kits	Kits	1	
	Rucksack, Medical Accessory Kits	1	
	Maintenance Kits	1	
	Purge Fitting Kits	1	
Lines, Ropes, Lanyards Straps, and Restraining Devices	Tethers	1	
	Restraint Assemblies	1	
	Straps	1	
	Snag Lines	1	
	Ropes	1	
	Life Lines	1	
	Strap Assemblies	1	

EQUIPMENT	PART NAME	CLEANLINESS CODE	APPLICABLE CHAPTER
Lighting Equipment	Glareshields	1	20
	Penlights	1	
	Light Bulb Assemblies	1	
	Utility Lights	1	
Medical Equipment and Supplies	Medical Injectors	1	
	Thermometers	1	
	Medical Packages	1	
	Emollients	1	
	Signal Conditioners	1	
Meters	Spotmeters, Automatic	1	
	Dispensers	1	
	Radiation Survey Meters	1	
	Bioinstrumentation Assemblies	1	
	Pneumograph Signal Consitioners	1	
	Dosimeters, Personal	1	
	Dosimeters, Passive	1	
Mounts, Brackets	Mounts	1	
	Brackets	1	
Optical Equipment	Optical Alignment Sights	1	
Portable Life Support System	Mask and Hose, Oxygen	4	
	Portable Life Support Systems and Remote Controls	3	
	Light Cartridges	1	
Post Landing Equipment	Post Landing Ventillation Ducts	1	
Potable Water Equipment	Ampules, Chlorination	2	
	Ampules, Buffer	2	
	Knobs, Syringe	1	
	Syringe Casings	1	
	Syringe Needles	2	
	Water Dispensers	2	
Pumps	Pumps	1	
Recording Equipment	Voice Recorders	1	
	Cassette Tapes	1	
	Battery Voice Recorders	1	

EQUIPMENT	PART NAME	CLEANLINESS CODE	APPLICABLE CHAPTER
Sanitation Supplies and Equipment	Dispensers, Tissue	1	20
	Utility Towels	1	
	Sanitation Supply Stowage Boxes	1	
	Cushions	1	
	Fecal Collection Assemblies	1	
	Inner Fecal Bags	1	
	Fecal Germicide Pouches	1	
	Wrappers	1	
Software - Paper Products	Tapes	1	
	Files, Flight Data	1	
	Checklists	1	
	Plans, Flight	1	
	Photographs	1	
	Data Systems	1	
	Procedures, Malfunction	1	
	Charts and Graphs	1	
	Crew Logs	1	
	Procedures	1	
	Updates	1	
	Photograph Logs	1	
	Clip, Flight Data File	1	
	Data Card Kit	1	
	Contamination Carriers	1	
	File Assemblies	1	
	Descent Aids	1	
	Book Clamps	1	
Suits	Suits, Soft	1	
	Suits, Hard	3	
	Pressure Garment Assemblies	4	
	Torso Limb Suit Assemblies	3	
Sun Shades	Sunglasses	1	
	Pouch, Sunglasses	1	
	Shades	1	
Survival Equipment	Kits, Survival	1	
	Tape Mending	1	
	Combination Survival Light Assemblies	1	
	Chemical Packet Assemblies	1	
	Desalter Kits	1	
	Sun Screens	1	
	Sheaths	1	
	Machetes	1	
	Water Containers	2	
	Sunglasses	1	

EQUIPMENT	PART NAME	CLEANLINESS CODE	APPLICABLE CHAPTER
Survival Equipment	Assembly Radio Beacons	1	20
	Spare Batteries	1	
	Connectors, Radio Beacons	1	
	Rucksacks	1	
	Life Rafts	1	
	Life Raft Inflation Assemblies	1	
	Sea Anchors	1	
	Sunbonnets	1	
	Manline Lanyards	1	
	Inflation System Pads	1	
	Tissue Dispensers	1	
Television Equipment	Lightweight Headsets	1	
	TV Subsystems	1	
	Universal Eartubes	1	
	TV Cameras	1	
	TV Camera Lenses	1	
	TV Cables	1	
	Handholds	1	
	Sun Filters	1	
	TV Brackets	1	
Timers	Timers, Interval	1	
Tools	Tool Set Assemblies	1	
	Tools	1	
	Tool Handles	1	
	Jack Screws	1	
Tunnel Equipment	Hatches	1	
Umbilicals	Feeding Valve Adapters	1	
	Umbilicals	2	